CHAPTER 1

1 INTRODUCTION

The purpose of this project was to provide Generation Expansion Planning division with a tailor-made user-friendly flexible computer model suitable for the evaluation and optimisation of alternative generation capacity and energy plans.

The objective was to develop the Eskom Production Scheduling system, by the end of 1990, which would form the foundation for the remainder of increments of the final provide Generation Expansion Planning model.

The current status of the system utilised is covered in a separate chapter.

1.1 Executive Summary

In reporting on the progress of the new Linear programming function, developed for the Generation Expansion Planning division (GEP), an overview of the literature surveyed is covered. This is followed by what currently is in place. The specification of the new system is then documented. A brief chapter on the

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ACKNOWLEDGEMENTS

Thanks to ESKOM's
Generation Expansion Planning Division,
Information Technology Department and
Systems Engineering Division
for providing this opportunity.

DEDICATION

To my Father God for giving me the ability to go beyond my apparent limitations,

AND

To my wife Denise for her support and encouragement, and Laura and Matthew

ABSTRACT

The purpose of this document is to report on the development of a Linear Programming function for the Generation Expansion Planning environment of Eskom.

This was achieved by researching the modeling methods employed in this and related fields of work. After establishing the scope of the work to be performed all the options were carefully assessed and it was decided to develop the Production Scheduling function first, as this would serve as the foundation for future work.

The requirements were specified after extensive discussion with the customer. These requirements were utilised to establish the formulae, including their bounds and constraints. These were in turn converted into the Linear Programming function. To facilitate the data input process a simple input facility was developed. To maximise the value of the results the report writer was developed to enable sensitivity studies to be performed. This work was later used as the foundation of the NewGex programme.

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

Lance Robert Botha

14th day of October 1994

RESEARCH AND DEVELOPMENT OF A LINEAR PROGRAMMING FUNCTION WITH SPECIFIC REFERENCE TO THE GENERATION EXPANSION PLANNING ENVIRONMENT OF ESKOM

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 1994

electricity generating systems and propose an optimum expansion plan.

These generation expansion computer programmes are designed to evaluate the cost of electricity generation and installation of new generating plant. Alternative generation expansion plans for long periods, ranging from 15 to 30 years, are evaluated to establish the optimum plan (i.e. least cost). A generation expansion plan has two major functions:

(1) electricity production simulation and

(2) capacity expansion optimisation.

Besides performing a large quantity of calculations, the generation expansion programmes provide a systematic means for the evaluation of the timing, type and size of new capacities which could be included in an expansion plan.

2.2 LP In The Power Utility Industry

It was in the early 1950's that mathematical programming techniques were developed and applied to generation planning. It was Masse' and Gibrat[1] of Electricite' de France who developed and solved a linear programming (LP) model of the generation

i) the planners have to examine more alternative technologies and sizes of generating units,

ii) the operating costs with different fuels is subject to different availabilities and inflation rates,

iii) devices to prevent health and safety hazards has become a significant portion of the operating costs (as much as 30 percent),

iv) long construction periods for (8 to 10 years or even longer),

v) uncertain load growth,

vi) fluctuating and high interest rates,

vii) a nuclear industry which has had numerous problems both while under construction as well as in operation, resulting in lower productivity and higher generation costs.

For these reasons, the planners are no longer able to rely on simplistic and intuitive decision making. They have to investigate the effects of various decision parameters and the possible future changes of these parameters. They have to answer many what-if type questions before a generation capacity plan is decided upon. This can only be achieved by utilising computer programmes that simulate the operation of the

CHAPTER 2

2 OVERVIEW

This chapter provides an overview and summary of the literature surveyed for this project. The purpose was to establish an understanding of Linear Programming and it's utilisation within the power utility industry, focusing particularly on Generation Planning.

2.1 History of Generation Planning

Until the mid-1960s, planning of generation (electricity capacity) expansion was relatively simple because of the steady increase of load growth and the rapid and technological advances in new and larger generating units with little public concern about health and safety hazards. The cost of electricity declined until the late 1960s when the trend reversed.

Since the late 1960s, decision making on capacity expansion has become increasingly more complicated for various reasons, LP was a well known and widely documented technique which reduces the time for new-comers to understand and use the model.

- conduct all studies using EGEAS[d] or POWRSYM only. This provided inadequate modelling options.

1.7 Reason for Selecting LP Technique

A high-quality LP package (Sciconic) which included a matrix generator and report-writer language was available on both the IBM mainframe and Apollo/HP workstation computing platforms. Any other optimisation technique would have required ITICS to develop their own algorithm which would have been a very complex and time-consuming task.

LP formulation would have allowed the addition or modification of constraints to be done relatively easily.

Energy constraints on production scheduling could be represented easily.

Considerable in-house experience with LP formulation existed and outside expertise was available at a price (SCICON - developers of Sciconic, universities etc.).

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d EGEAS - Electric Generation , Expansion Planning Analysis System programme.
POWERSYM - Power System Probabilistic Simulation programme.

(covered in more detail in the next section),

- better editing facilities on IBM and Apollo/HP,
- Sciconic is more computationally efficient than APEX (by a factor of about 3).

1.2.5 Risks

Development of NewGax is a task which might have been too demanding for the resources available in GEP and Information Technology Inter-Connected Systems (ITICS) and the project might have had to be scaled down, contracted out (resulting in skill not remaining within Eskom) or dropped altogether.

1.2.6 Alternatives

A number of potential alternatives did exist viz.

- to ensure that the CDC mainframe would remain available to Eskom. This was a costly and extremely difficult option,

- acquire a new generation expansion planning model from another utility, institution or software vendor. This was also costly and the software was inflexible,

b) arbitrarily weighting the normal* and Worst case to improve the production schedule requires roughly twice the amount of equations and is a technique which has no theoretical foundation; the new model should use a technique which could enable the calibration of individual load factors using EGEAS or other models,

c) the Load Carrying Capability (LCC) programme, which was being used by Generation Expansion Planning, was computationally very inefficient, unreliable and outdated; the new model should make use of new theories to represent the Loss Of Load Probability (LOLP) constraints as linear equations.

1.2.4 Opportunities

A number of opportunities which could be realised viz.

- up to date linear programming package, Sciconic, which runs on IBM mainframe and Apollo/HP workstation

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* When average availability of the power stations, average production levels at the collieries and average hydro energy is used in compiling constraints, the solution will provide the best way to expand and operate the system under average conditions only - the Normal Case. This will not allow for periods when outage rates are above average, when below average production levels persist at the collieries or when drought limits the hydro energy available, therefore the Worst Case is required.

editing of input files every time a new study was started.

Poor data validation, especially consistency checks between related data records.

The situation was aggravated by the inflexible reports that could be produced and the poor archiving facilities that existed.

1.2.3 Modelling shortcomings

Model shortcomings which could possibly be avoided by NewGex;

a) simultaneous optimisation of the whole study period could be very costly in terms of computer resources; year-by-year optimisation might produce acceptable results.

obsolescence. This switch-over was to render the old model useless. Converting CDC-FORTRAN to standard FORTRAN and APEX input/output format to Sciconic[b] input / output format was almost impossible and would have consumed a great amount of time.

1.2.2 GEX shortcomings

A number of programming shortcomings identified in the GEX model that could be avoided in NewGex are listed;

a) Programming code

The GEX code had been modified often in a quick-and-dirty reactive manner resulting in reduced reliability. It did not have a proper modular structure, making it difficult and risky to modify.

The matrix generator was written in FORTRAN instead of a specialised language reducing flexibility in terms of implementing new or modified equations.

b) Input/output facilities

No data base was available resulting in laborious

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[b] Sciconic- Linear programming code generator and optimisor based on the UNIX environment.

agreed that this would be the foundation upon which the rest of the NewGex model would be developed.

Chapter on formulation documents the various formulae included in the new system. A brief description of each is provided and ends with the objective function which links the various variables, bounds and constraints together.

The final chapter concludes the project on the LP function of the Eskom Production Scheduling system.

1.2 Need to Replace GEX Model

This section lists the main reasons why a new modelling facility was required by the customer.

1.2.1 Urgency

The CDC Cyber mainframe (including APEX* and CDC-FORTRAN) was to be phased out and replaced by an IBM mainframe computer by the end of 1990 due to technical

* APEX - A linear programming optimising programme developed for the CDC environment.

house, is discussed and documented. A number of GEX's features are covered, such as

- The linear representation and constraining of transport requirements,
- Scenarios that allow for average and extreme operating conditions and demand,
- Reserve requirements for planned and forced outages.

With an understanding of the applications of LP in the power utility established and an in depth knowledge of the current system achieved the user's requirements were documented in the following chapter. Additional points covered include et-al.

- Objective of the project
- Available resources and their responsibilities
- Strategy to complete the project
- Scope and methodology of studies to be performed.

The chapter on computer software covers the software utilised in developing the new system, NewGex . Only an overview is provided and includes a brief description of a number of the problems experienced.

The rest of report focuses only on the production scheduling / planning part of the LP model. It was computer software utilised is included. This leads to the chapter which contains a listing and description of the formulae included in this aspect of the overall new programme to be developed. The final chapter has a number of concluding remarks.

The overview focuses on documenting the literature surveyed. The history of generation planning is covered and the application of Linear Programming (LP) in this environment. The representation of electric power demand and its linear representation is illustrated. The objective function and a number of the basic constraints are discussed. The various constraints are then covered viz.

- Demand and supply of electricity
- Plant capacity and the impact of availability
- Hydro-energy
- Pumped Storage
- Impact of the Z-substitute alternative
- Replacement and expansion
- The inclusion of transmission

The following chapter covers the history and current status of the application of LP in Eskom's Generation Expansion Planning division (GEP). The existing LP system Generation EXpansion system (GEX), developed in all y, p, s and \$ = hydro station

$$\boxed{ST_{\$yp+1} + \sum_{\$=1}^{\$} (SW_{\$yps} * GO_{\$yps}) \leq ST_{\$yp} + WI_{\$yp}}$$

- $ST_{\$yp}$ is the energy stored at the beginning of the period p in hydro-station \$, and
- $GO_{\$yps}$ is the power output in year y, period p and slice s by power station \$,
- SW_{yps} is the slice width in year y, period p and slice s,
- $WI_{\$yp}$ is the water inflow in period p, adjustments must be made for seepage and evaporation.

If $STC_{\$yp}$ is the storage capacity of reservoir and $ST_{\$yp}$ the energy stored at the beginning of the period (p) at a hydro power station (\$), then

$$\boxed{0 \leq ST_{\$yp} \leq STC_{\$yp}}$$

2.6 The Capacity Constraint

This is the operating capacity of a plant that accounts for availability, i.e. the maximum capacity available for generation. This is the constraint that ensures that the utility can cope with varying availability

all \$, y, p and s

$$\boxed{GO_{\$yps} \leq AV_{\$yp} * IGC_{\$yp}}$$

- $GO_{\$yps}$ is the power output for the power plants in year y, period p and slice s by power station \$,
- $AV_{\$yp}$ is the availability factor for plant \$ at period p,
- $IGC_{\$yps}$ is the installed generating capacity of plant \$ that can be sent out in a specific slice.

2.7 Hydro-Energy Constraint

A mathematical representation of how the potential energy stored in the dam is converted to power, The peak demand (capacity) constraint, where the available installed capacity exceeds or equals the demand plus reserve margin. This constraint will be covered in details in a later chapter.

all y, p and s=1

$$\boxed{\sum_{\$=1}^{\$} \sum_{s=}^{S} (AV_{\$yp} * GO_{\$yps}) \geq PD_{yp} * (1+RM_{yp})}$$

- $AV_{\$yp}$ is the availability factor for plant \$ at period p,
- $GO_{\$yps}$ is the power output for the power plants in year y, period p and slice s by power station \$,
- PD_{yp} is the peak demand for planning period p in year y, and
- RM_{yp} is the reserve margin for year y and period p.

- $FCI_{\$yp}$ is the fixed cost per unit capacity of power station \$ in year y, period p, and
- $GC_{\$yp}$ is the capacity of power station \$ in year y, period p.

2.5 The Demand / Supply of Electricity

There are two constraints associated with demand

- instantaneous demand and,
- peak demand.

The instantaneous constraint ensures that the demand in a particular slice will be satisfied by the total power generated by the various power stations.

All y, p and s

$$\boxed{\sum_{\$=1}^{\$} GO_{\$yps} \geq DM_{yps}}$$

- $GO_{\$yps}$ is the power output for the power plants in year y, period p and slice s by power station \$, and
- DM_{yps} the demand satisfied by power plants, \$ = 1,...,\$, in year y, period p and slice s.

regardless of the amount of electricity produced, viz. interest payments, certain primary energy costs.

The indices associated with the variables and constraints that are used in the objective function variables and or a constraints are listed below.

$ power source (power station ...)

y year

p period (including year index)

s slice (including year and period indices)

Minimise

$$\text{COST} = \sum_{\$=1}^{\$} \sum_{y=1}^{Y} \sum_{p=1}^{P} \sum_{s=1}^{S} (CGO_{\$yp} * SW_{yps} * GO_{\$yps}) + \sum_{\$=1}^{\$} \sum_{\$=1}^{Y} \sum_{\$=1}^{P} (FCI_{\$yp} * GC_{\$yp})$$

- $GO_{\$yps}$ is the power output in year y, period p and slice s by power station \$, and is the only variable for a specific slice,
- $CGO_{\$yp}$ is the cost of producing one unit of energy in year y, period p and slice s,
- SW_{yps} is the slice width in year y, period p and slice s,

are related to the corresponding load duration curve for each period. Each load duration curve is approximated by a series of histograms ($s = 1....S$) of width Sw_s (Figure 2-4). These widths are usually not of the same length, with those at the beginning of the period, where greater accuracy is required, being shorter than those at the end. For ease of presentation each histogram will be referred to as a slice of the load duration curve (Figure 2-5).

2.4 The Objective Function

The goal a power utility is to supply electricity at as low a cost as possible, by minimising the production costs[5]. It is on this premise that the objective function (cost function) is developed to minimise the cost of operating the existing system and installing and operating additional plant.

The costs associated with existing plant are fixed costs and operating costs (variable costs). Fixed costs are those costs not directly associated with the production of electricity that have to be incurred

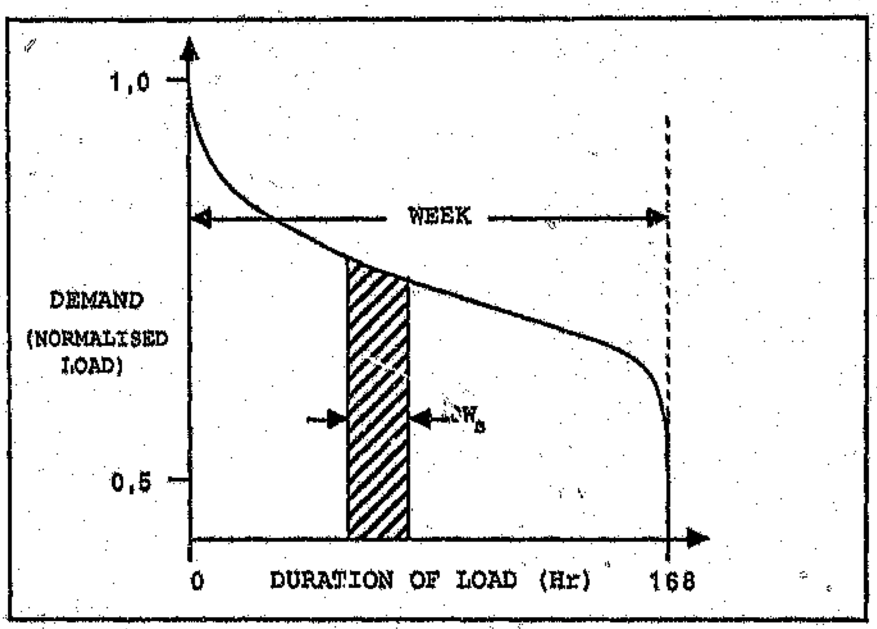

Figure. 2-4 LOAD DURATION CURVE

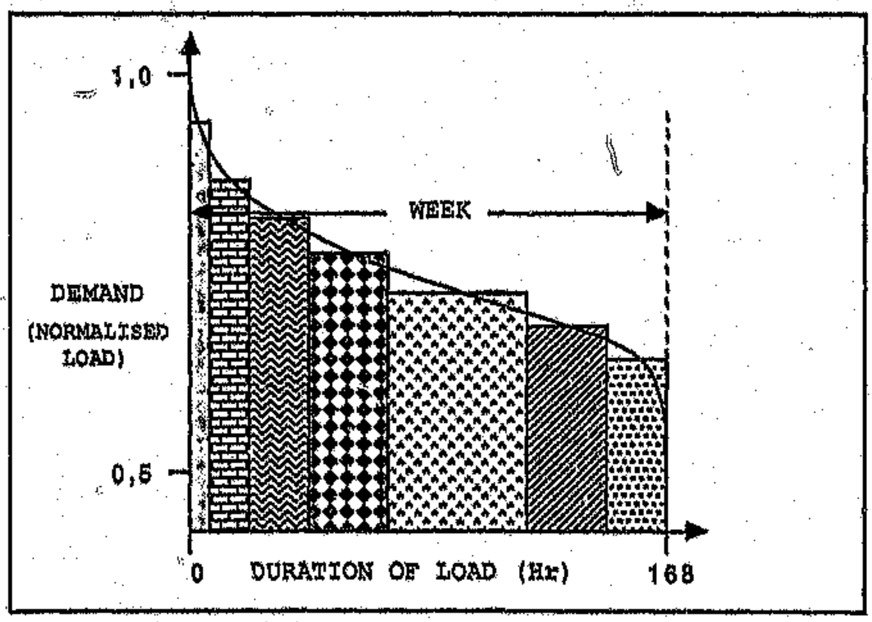

Figure. 2-5 LOAD DURATION CURVE - HISTOGRAM

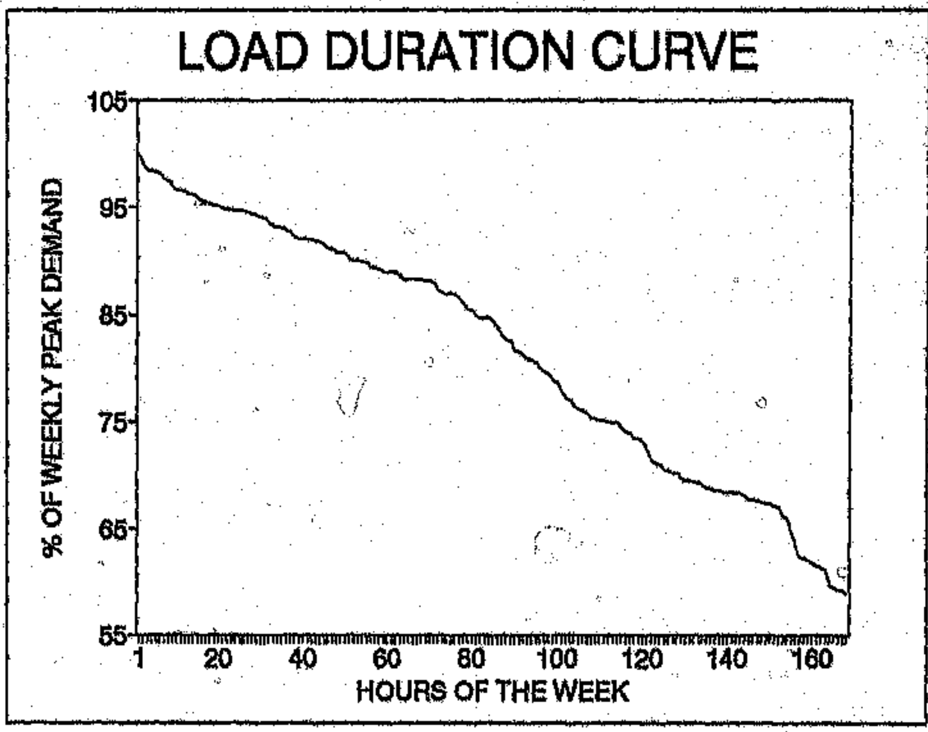

Figure. 2-3

load duration curve to represent the demand for electricity. The planning interval must be broken down into years (y=1,...,Y), and each year into a number of periods (p=1....P). The generation requirements per period

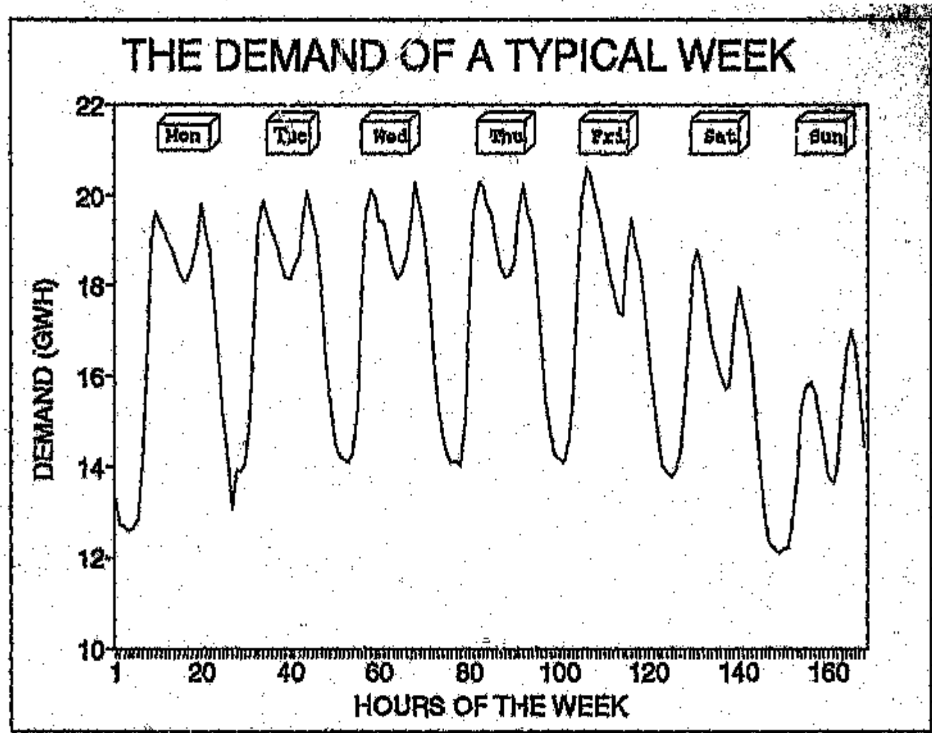

Figure. 2-2

the demand curve of a typical week (Figure 2-2) are the two daily peaks, at about 9:00 and 19:00 respectively, and that the weekly peak usually occurs on Friday mornings.

Most LP models used for generation planning[3] and generation expansion planning[4], make use of a weekly

2.3 Representing the Load on the System

In the South African context, the analysis of historical records show that, in terms of the annual peak demand, the weekly peak demand throughout the year follows a reasonably predictable pattern (Figure 2-1). The annual weekly maximum curve will vary slightly with the growth in electricity demand. In Figure 2-1, the weekly maximum curves of Year-1 and Year-2 have been normalised and it can be seen that the energy demand in Year-1 was the larger of the two, due to the smaller drop in the weekly maximum after the winter peak.

If the hourly demands during a week (Figure 2-2) are plotted as a fraction of the weekly maximum demand, in descending order of magnitude, the weekly load duration curve can be established (Figure 2-3).

The weekly load duration curve will vary slightly with the growth in electricity demand. This will be evident by the existence of a more peaked weekly load duration curve. This is primarily as a result of domestic peak loads increasing. Some interesting features to note on

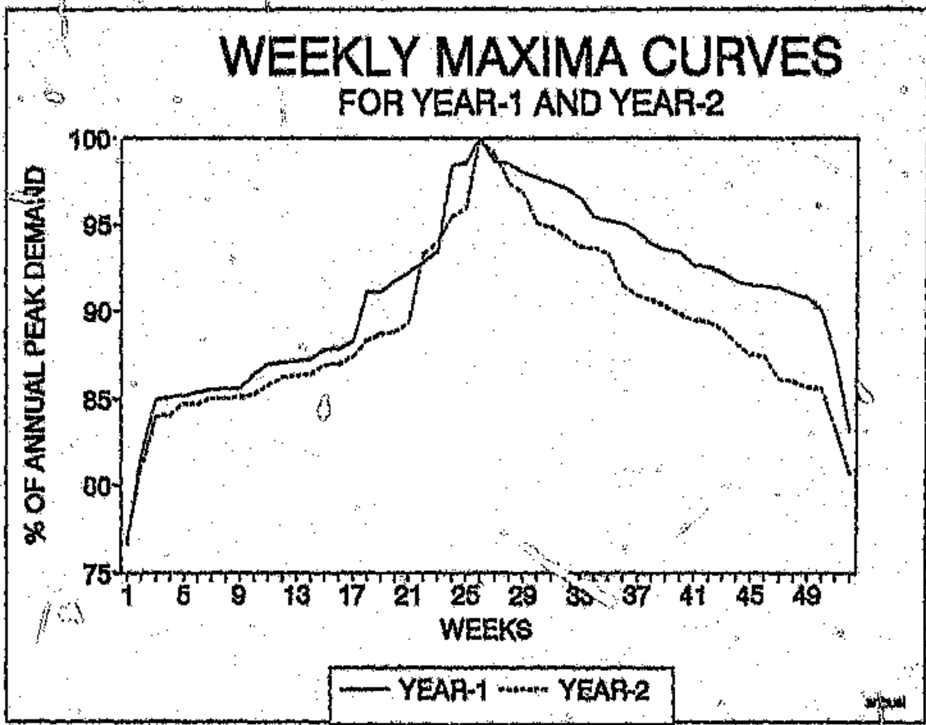

Figure. 2-1

- Method of Z-Substitutes
- Replacement and Expansion
- Inclusion of Transmission

planning problem. This initial work has served as the basis for many LP models that have been developed for generation planning and generation expansion planning departments in utilities throughout the world.

The models are usually developed, with the prime objective being, to enable the planning engineer to determine the optimal investment in generation expansion[2] or operation of the existing power system, subject to a number of imposed constraints.

To enable the use of linear programming a number of aspects of power generation have to be considered. These are;

- The Objective Function
- The Load on the System
- The Demand / Supply of Electricity
- The Capacity Constraint
- Hydro-Energy Constraint
- Pumped Storage - Constraint

CHAPTER 3

3 CURRENT STATUS

The history and current status of the application of LP in Eskom's Generation Expansion Planning division (GEP) is covered in this chapter.

3.1 Generation Expansion Planning

The main activity of the Generation Expansion Planning division starts with the prediction of future electricity consumption which is provided and revised annually by the Power Marketing Department.

Once these predictions have been approved, it is GEP role to determine how much, when and what type of new generating plant should be constructed by the Engineering Group. This includes exercises in determining when and what old power stations should be taken out of service.

The expansion programme should ensure that the needs of Eskom's customers are satisfied at the lowest possible

c) If the transmission system is designed to transmit energy in large quantities, the markets of regions rich in energy resources (fossil or hydro) can be expanded, and regions less rich can import the cheaper energy.

d) With interconnection, larger units can be installed embodying considerable economies of scale.

These four aspects of the transmission system - the pooling of reserve capacity, the pooling of peak capacity, the opening of markets to regions rich in low-cost resources, and economies of scale - can make large savings in comparison to the costs of the transmission lines and transmission losses.

It is beyond the scope of this work to consider transmission any further. This matter is covered in more depth in Anderson's(5) document.

- G_{syp} is the capacity of power station s in year y, period p.

How these expansion plans are implemented is the task of the expansion planning engineer who will perform a number of what-if tests on a specific implementation and then make his proposal.

2.11 Inclusion of Transmission.

Transmission systems reduce costs of supply in four ways.

a) If regions are interconnected, in the event of generator failure in one region, it is possible to call upon the reserves of other regions; the required reserve capacity is less with interconnection than without.

b) If peak demands occur at different times in different regions, then interconnection permits peak power capacity to be exported and imported, and the aggregate peak demand can be met with less capacity.

associated directly with fixed maintenance and operating costs.

The discounted, fixed maintenance, and operating costs of plant \$, in year y, period p is denoted by $CX_{\$yp}$. The problem is to decide how much of this plan should remain in service in year y. Let $GC_{\$yp}$ be the amount of plant \$ in service in year y, period p. The objective and the constraints follow much the same pattern as before. Using the same notation the objective function now becomes,

<u>Minimise</u>

$$\boxed{\begin{aligned} COST = & \sum_{\$=1}^{\$} \sum_{y=1}^{Y} \sum_{p=1}^{P} \sum_{s=1}^{S} CGO_{\$yp} * SW_{yps} * GO_{\$yps} \quad + \\ & \sum_{\$=1}^{\$} \sum_{y=1}^{Y} \sum_{p=1}^{P} (FCI_{\$yp} + CX_{\$yp}) * GC_{\$yp} \end{aligned}}$$

- $CGO_{\$yp}$ is the cost of producing one unit of energy in year y, period p and slice s,
- SW_{yps} is the slice width in year y, period p and slice s,
- $GO_{\$yps}$ is the power output for the power plants in year y, period p and slice s by power station \$, and
- $FCI_{\$yp}$ is the fixed cost per unit capacity of power station \$ in year y, period p.

system without a specific power station. This may arise because of rising operating and maintenance costs relative to those of new plant, or because sites for new power stations are not available and old ones need to be scrapped to make room for new, larger stations and increased / more stringent pollution legislation. Similarly if the demand increases it may be necessary to expand the system by building a new power station.

An accurate treatment of replacement or expansion requires explicit separation of fixed annual operation and maintenance costs from other costs. These fixed costs are usually added to the annuitised charges on capital, while the variable maintenance costs are added to the other variable operating costs. Following Masse' and Anderson[5] the variable $GO_{\$yps}$, power output for a plant, is extended to include the amount of plant scrapped or new plant to be commissioned of type \$, in year y, period p, and write capital cost terms in the objective function such as $CGO_{\$yp}$, where $CGO_{\$yp}$ equals the fixed period costs plus annuitised charges on capital. This can however lead to solutions which scrap plant before capital costs have been accounted for by the annuities. Since the decision to install new plant requires a new decision variable, this variable can be

$$\boxed{IGC_{syi} \geq \sum_{s=1}^{S} Z_{syis}}$$

The GO variables, which had to satisfy plant capacity constraints on every portion of the load duration curve can thus be replaced , with new non-negative variables, by the Z-substitutes, which satisfy one constraint for the whole curve.

Introducing The Z-variable reduces the number of constraints in an LP model substantially and allows linear programming to be applied to larger problems. Although the introduction of the Z-substitutes increases the matrix density there is a considerable reduction in model size. Typical improvements in performance reported[8] and confirmed[9] are reductions in the number of constraints by as much as 80% and increases in the speed with which the computer performs the optimisation by a factor of between two and five.

2.10 Replacement and Expansion.

Optimum replacement of a power station usually occurs when it is cheaper to expand and operate the power

- $GO_{\$yps}$ is the power output for the power plants in year y, period p and slice s by power station \$.

The capacity constraint is

for all s

$$\boxed{IGC_{\$yp} \geq GO_{\$yps}}$$

- $IGC_{\$yps}$ is the installed generating capacity of plant \$, i.e. the same plant as $GO_{\$yps}$, that can be sent out in year y, period p and slice s.

Therefore by definition

for all s=1,...,S-1

$$\boxed{Z_{\$yps} = GO_{\$yps} - GO_{\$yps+1} \geq 0}$$

- $Z_{\$yps}$ is the decrease in power output of a certain plant for the period s to s_{i+1}

and

$$\boxed{Z_{\$yps} \geq GO_{\$yps} \geq 0}$$

it follows

$$\boxed{Z_{\$yp1} + \dots + Z_{\$yps} = \sum_{s=1}^{S} Z_{\$yps} = GO_{\$yp1}}$$

and

for all s

$$\boxed{IGC_{\$yp} \geq GO_{\$yps}}$$

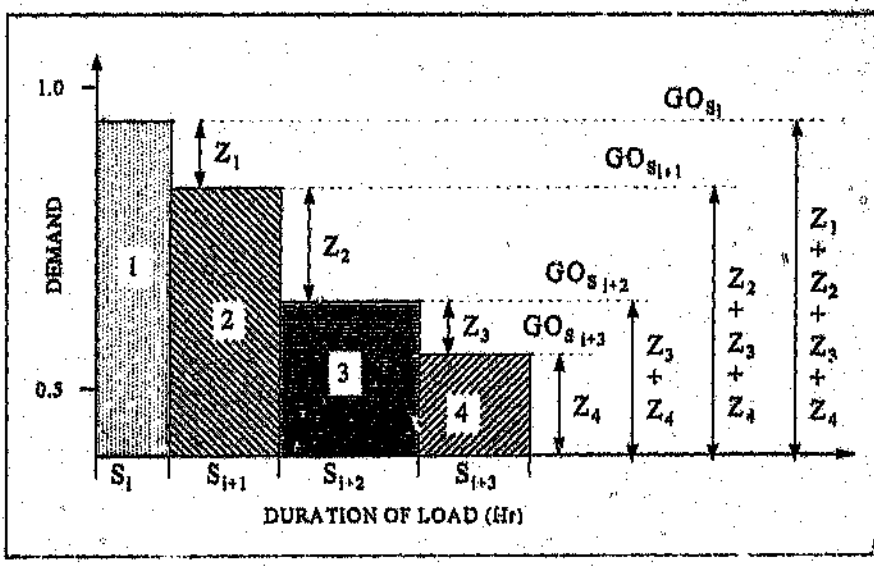

Figure. 2 - 7 Z - SUBSTITUTES

one block to the next. If such variations occur, the time span of the load duration curve is too long and should be reduced.

Let Z_{S_s} be the decrease in power output of a certain plant for the period s_i to S_{i+1} (Figure 2-7). Then it follows from the load duration curve that

for all s

$$GO_{Sys\,s} \geq GO_{Sys\,s+1}$$

2.9 Method of Z-Substitutes

The main disadvantage of early LP models was that the number of constraints would soon become prohibitively large as the number of planning intervals, plant types, generation groups and blocks in each load duration curve increased. Attention was turned to different approaches to the problem of LP model retrieval and the method of Z-substitutes, a general technique attributed to Beal (referenced in Andesons paper[7]), was developed.

This method is based on the observation that the Load Duration curve can broken into a number of blocks for each interval of the planning period (Figure 2-7). Then going from one block S_i to the next S_{i+1} along the time axis of the Load Duration curve, as the demand level decreases, the output of any plant will not be increased. In fact it will either remain the same as before, or it will be reduced. This deduction is valid provided that the plant availabilities, production costs, and hence the merit order (i.e. "the order in which the power stations are called upon to generate electricity) does not vary from

In addition, it is necessary to implement the pumped storage constraint to ensure that the energy generated in a period p is equal to the energy used in pumping, multiplied by cycle efficiency of the plant.

All y, p and where \$ = pumped storage

$$\sum_{s=1}^{S} SW_{yps} * GO_{\$yps} - EFF_{\$yp} * \sum_{s=1}^{S} (SW_{yps} * PL_{\$yps}) = 0$$

- SW_{yps} is the slice width in year y, period p and slice s,
- $GO_{\$yps}$ is the power output for the pump storage power plants in year y, period p and slice s by power station \$,
- $EFF_{\$yp}$ is the overall efficiency of the pumped storage station, and
- $PL_{\$yps}$ is the energy required to pump the water to storage.

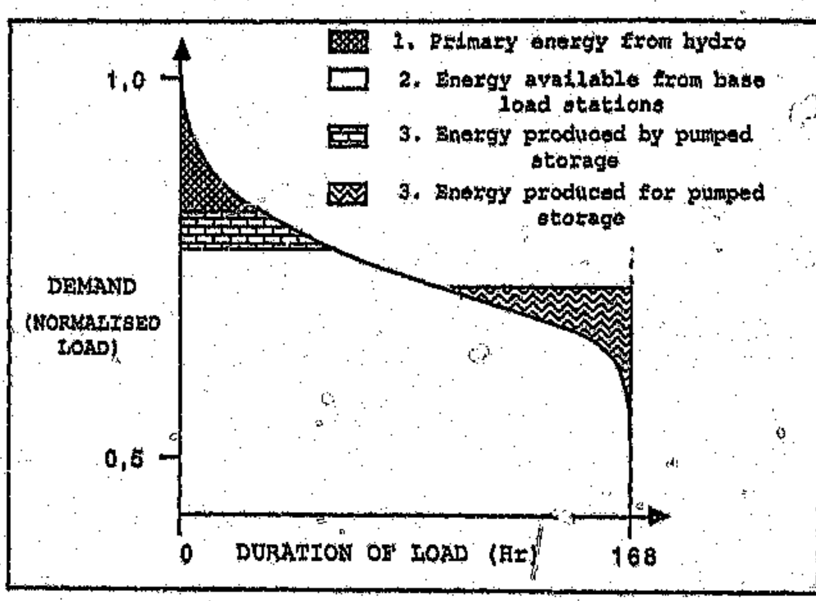

Figure. 2-6 PLANT MIX ((4)-(3)+(2)+(1)>= ENERGY DEMAND)

- $PL_{\$yps}$ is the energy used to pump the water to storage and is contributed by other stations on the national grid, and
- DM_{yps} the demand satisfied by power plants, $\$ = 1....\$$, in year y, period p and slice s.

2.8 Pumped Storage - Constraint

The introduction of a pumped storage[6] station into the national grid was to do peak shaving, i.e. to generate at the peak demand, and to pump water to storage in the troughs of the demand cycle (Figure 2-6), by utilising excess energy. The result is a reduction in fuel costs to the whole generating system by storing energy at low load periods and generating at high load periods.

The power generated by all the power stations must be equal to the total power demanded including the power used by the pumped storage station. The instantaneous demand constraint must be modified as follows,

All y, p and s

$$\boxed{\sum_{\$=1}^{\$} (GO_{\$yps} - PI_{\$yps}) \geq DM_{yps}}$$

- $GO_{\$yps}$ is the power output for the power plants in year y, period p and slice s by power station \$, Overall availability and forced outage rates are determined from past records for existing plant and assumed performance of future plant.

The difference between the installed capacity and average that is sent out as a result of plant availability, represents the average allowance required for forced and planned outages. The amount of planned outage (that required for general overhauls and inspections) can be determined from the calculated forced outage which is based upon the assumed forced outage rates and the allowance needed for planned outage.

3.3.6 Load carrying capability

Having established the average requirements for planned maintenance in this way, the reserve needed to cater for forced outages with a given degree of security of supply can be established using probability methods.

For a given station having sets with known forced outage rates, the probability of any number of sets being out of service at the same time is established using the binomial probability formula of the time it is possible to wait until the night of the next weekend to carry out the repairs, when the demand on the system is low. This type of outage does not require any additional reserve as it can be scheduled when the load permits. On the other hand, if the repair work is not completed before the next weekday peak, the portion of peak time when the set is still out of service must be treated as forced outage of the first category.

3.5 Routine maintenance reserve

Planned outage / general overhaul rates are based on the long term maintenance policy and on the various types of plant involved. At the old power stations where the set size does not exceed 30 MW, the maintenance of the boilers does not necessarily cause a reduction of output as there are more boilers than turbo-generators. At stations where there is one boiler per turbine, but where there is also a steam range (60 - 200 MW sets), the boiler overhauls do affect the overall availability of the station, but less than at the large sets equipped with reheat (300 MW and larger sets) where there is not possibility of cross-feeding.

when and what amount of additional capacity to install, at the same time.

3.3.4 Forced outage reserve

Forced outages can be divided into three categories, namely

a) Pure forced outage

This category of outage occurs when a sudden breakdown forces the complete generating unit out of service without any delay. Most electrical faults and the mechanical faults affecting bearings, belong to this category.

b) Partial forced outage

This category outage forces an immediate reduction of the unit output, but does not require its complete shutdown. Coal mill and fan breakdowns are typical of this category of outage because there are always several such auxiliary plants.

c) Deferred forced outage

This category of forced outage occurs because they do not require the set to be shut down immediately. Most

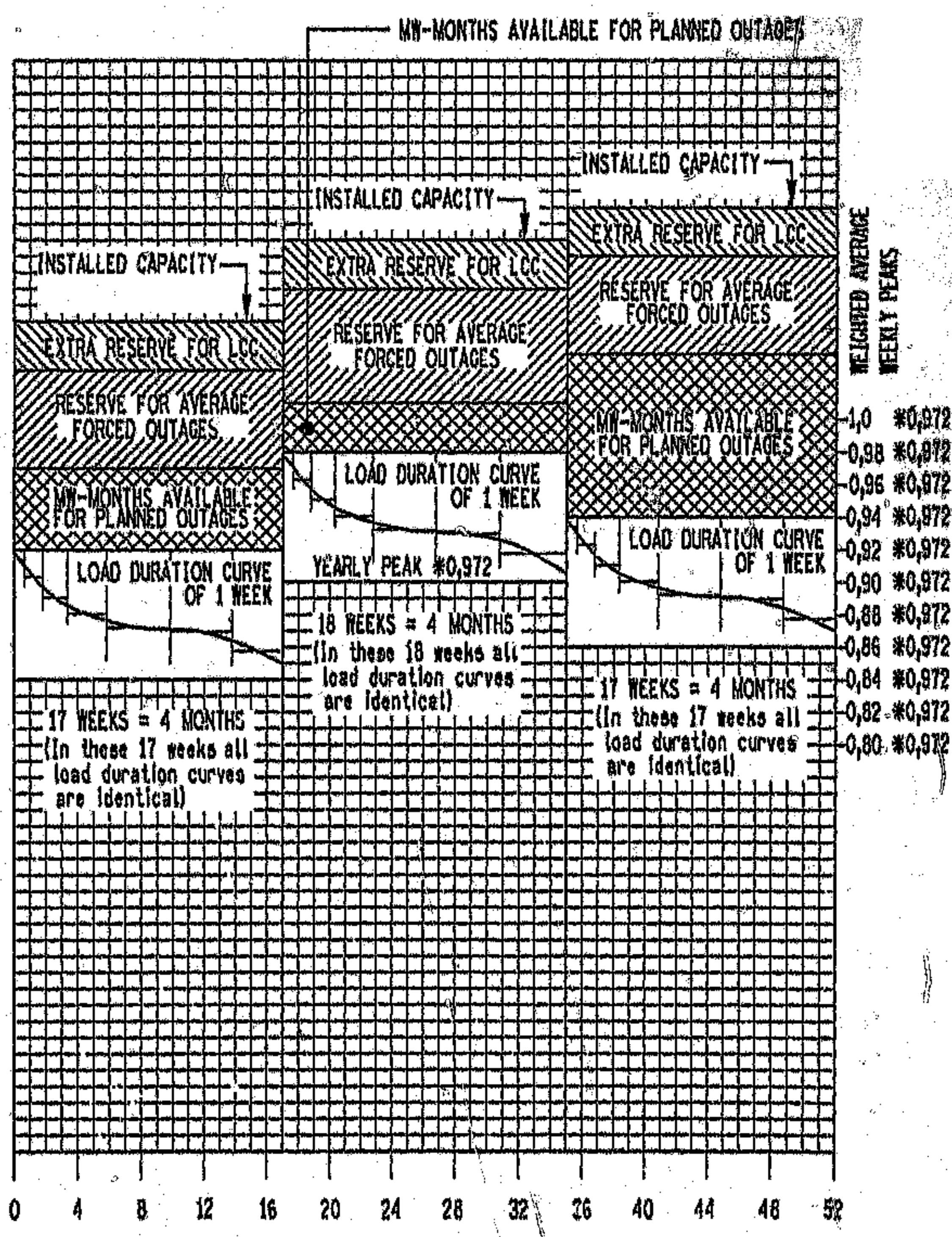

Figure 3-2 Load Representation And Reserve Requirements

If there was no load growth, the installed capacity would remain constant and thus the reserve and maintenance would be scheduled in such a way that the sum of the maximum demand of every week plus the amount of plant on maintenance at the time of this demand is kept at a constant minimum value throughout the year.

If there is load growth, additional generating capacity is provided from time to time. The optimum maintenance programme depends on how much extra capacity is installed in a year. A reasonable modelling simplification is to add capacity at the beginning of each four-monthly period so that the installed capacity increases in equal steps as illustrated on Figure 3-2. Maintenance scheduled on this assumption may require adjustment to meet the actual situation, as the size of the sets added and the fact that sets are not necessarily added in each four-monthly period.

This situation is allowed for in computer studies by permitting it to schedule the maintenance of one or two large stations. This enables the computer to determine

In the model a probability of occurrence may be assigned to the average and extreme conditions (usually called the normal and worst case). If, for example, 25% is allocated to the extreme conditions and 75% to the average conditions, the production costs making up the objective function take this allocation into account.

Such an allocation is necessary as the penalty of production costs, at a lower than average availability, is higher than the savings when the availability is higher than average. The cost of production versus the availability of the system is not a linear relationship, as the cost of production rises faster than the rate of deterioration in availability.

3.3.3 Reserve for planned maintenance

After the load representation has been determined the maintenance work can be scheduled. The objective of this exercise is to keep the required installed generating capacity of the system as low as possible while fulfilling the maintenance requirements dictated by the maintenance policy.

phased in to provide coal, from the time that the first of the six power generating units requires fuel until all six units require coal.

3.3.2 Average and extreme conditions

If, in the constraints, use is made of average availability of the power stations, average production levels at the collieries and average hydro energy, the solution will provide the optimal best way to expand and operate the system under average conditions only. This will not allow for periods when outage rates are above average, when below average production levels persist at the collieries or when drought limits the hydro energy available.

To cater for the adverse conditions, it was necessary to consider the generating system twice in meeting the demand:

- once with average conditions of plant and availability and
- once with extreme conditions of plant and energy shortage.

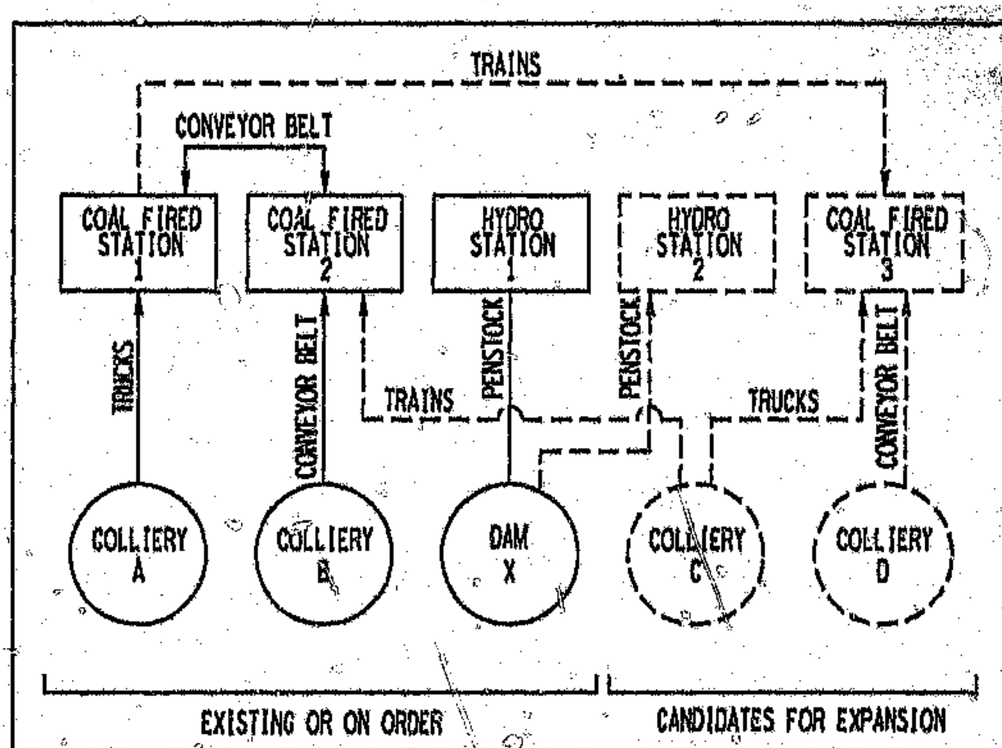

Figure 3-1 Transportation Representation

supplied by a colliery or water source. Normal practice is that a colliery becomes tied to a power station.

This means that once the contract is agreed upon coal is only produced for the one power station. If it is considered that it takes close to ten years to build a modern 'SIX PACK' power station, a colliery has to be

3.3 GEX Features

To obtain the maximum use of the LP methodology a number of special features, in addition to those covered in chapter one, were designed into GEX. This improved the value of the final results and enabling the testing of additional scenarios.

The more interesting of these features are now discussed.

3.3.1 The transport problem

This problem arose when it became necessary to simulate a network of power stations linked to primary energy sources via transport channels. This allowed the transportation of coal from one coal source to more than one thermal power stations (Figure 3-1). Similarly, one dam could supply more than one hydro station.

This section of the programme only allowed a maximum of three destinations per colliery or water source. The number of destinations is limited as Eskom does not have nor intends to have more than three power stations

December 1975 did not mark the end of the LP development as the programme, now called 'GEX' for Generation Expansion, was enhanced until the early 1980's. These enhancements include the development of a Matrix Generator, Report Writer, a Matrix Splitter, Integer Programming, and the inclusion of the Z - substitutes methodology. Further changes were made to the programme to increase the value of the output, remove programming errors, and to interface to other computer technologies as late as 1989.

Therefore, the problem of finding an economic expansion programme, however simple it appears at first glance, is in fact complex and requires the use of computers.

3.2 History of LP in Generation Expansion Planning

The application of Linear Programming to Generation Planning, in Eskom, came into its own 1974. The team consisted primarily of two people, one from the Generation Planning group and the other from the Information Systems group.

The progress of the project was as follows[10],

Project definition	June 1974
Systems Design	October 1974
Systems Programming	February 1975
User Tests	May 1975
Implementation	June to December 1975.

While developing the programme extensive work was being done by Rubbers[12] to determine and collect data to be used by the LP model.

cost, while complying with good reliability of supply and with limited impact on the environment.

GEP's work ends with a presentation to the Eskom Management Board where the various alternatives are outlined for a new expansion programme. This includes the recommendation of certain proposals.

Various types of generating plant (coal-fired, nuclear, hydro, pumped storage, combined cycle gas-fired stations and gas turbines) have different characteristics, such as:

- levels of reliability
- maintenance requirements
- operation requirements
- energy limitations
- efficiencies
- construction, operating costs and life cycle costs.

4.5 Generation Expansion Planning Methodology

The customer proposed that the programme be developed incrementally. The sequence in which the development was carried out was determined by what operational advantages could be achieved from each of the increments. The individual sections are listed briefly with a number of the issues considered.

a) Optimisation of present value of production and capital cost.

b) Reliability criteria;

- Reserve margin (25%),
- Loss of load probability (LOLP) at four-monthly peak hour (10%),
- LOLP at average four-monthly weekly peak hour (4.1%),
- LOLP of daily peak hour (6 d/y),
- Loss of load hour (LOLH) (22h/y),
- Unused Energy (UE) (.007%) cost to customers (1 to 5 R/KWH).

a) Evaluation of alternative plans:

- focus on production scheduling / planning (e.g. capacity factors),
- performing present value, escalated or constant Rand cost projections, and
- undertaking reliability evaluation scenarios (e.g. Load Carrying Capability, Loss Of Load Probability, Unused Energy)

b) Expansion plan optimisation:

- continuous or integer phasing of commissioning or decommissioning of plant, and
- plant mix studies (e.g. thermal or pumped storage)

c) Long-term budget.

A list of the type of studies done by GEP are listed in Appendix B.

Technology Inter Connected Systems (ITICS) staff were;

- develop, test and document the model,
- design and develop the database, and
- project co-ordination and control.

4.3 Strategy

Due to urgency of the project and the rather limited resources available, the development of the new model was to be based on the experience gained with the GEX model. Furthermore, the Operations Research expertise of ITICS was to be utilised in selecting the right methodology and ITICS was responsible for adopting the right approach for generation expansion studies.

4.4 Scope of Generation Expansion Planning Studies

GEP studies performed ostensibly fall into the following categories;

CHAPTER 4

4 USER REQUIREMENTS

4.1 Purpose and Objective

The purpose of this project was to provide Generation Expansion Planning division with a tailor-made user-friendly flexible computer model suitable for the evaluation and optimisation of alternate generation capacity and energy plans. The objective was to develop the Eskom Production Scheduling system, by the end of 1990.

4.2 Responsibility and Involvement

The GEP staff were primarily responsible to assist in the establishing of a methodology and specification of the model, and then to assist in testing and documentation. The responsibilities of the Information annual production expenses exceed those for capital, there are often significant differences between expansion programmes corresponding to each of these two objectives.

Once the LCC's are calculated for all possible combinations of new plant that could be added to make up the capacity shortfall, the computer optimisation programme selects the alternative which will meet the minimum total costs.

(ii) With a loss of load probability of six days every ten years, the optimum set size is 600 MW for all forced outage rates considered.

From Figure 3-4 it can be seen that the economic penalty is higher, in the case of poor reliability, if the system is expanded with large sets as opposed to more sets of a smaller capacity. Assuming the results of the computer studies predict that it is economical to install very large sets, a balcnce will have to be struck between a non optimum solution of small sets involving little risk and an optimum solution of large sets which might turn into a near disaster if expected reliability does not materialise. In other words, the economic advantage of very large sets should be substantial before a decision is taken to include them in an expansion programme.

To ensure an economic expansion programme, it is not so necessary to ensure that construction costs are kept to a minimum as to ensure that the total of production plus capital costs are kept to a minimum, and since

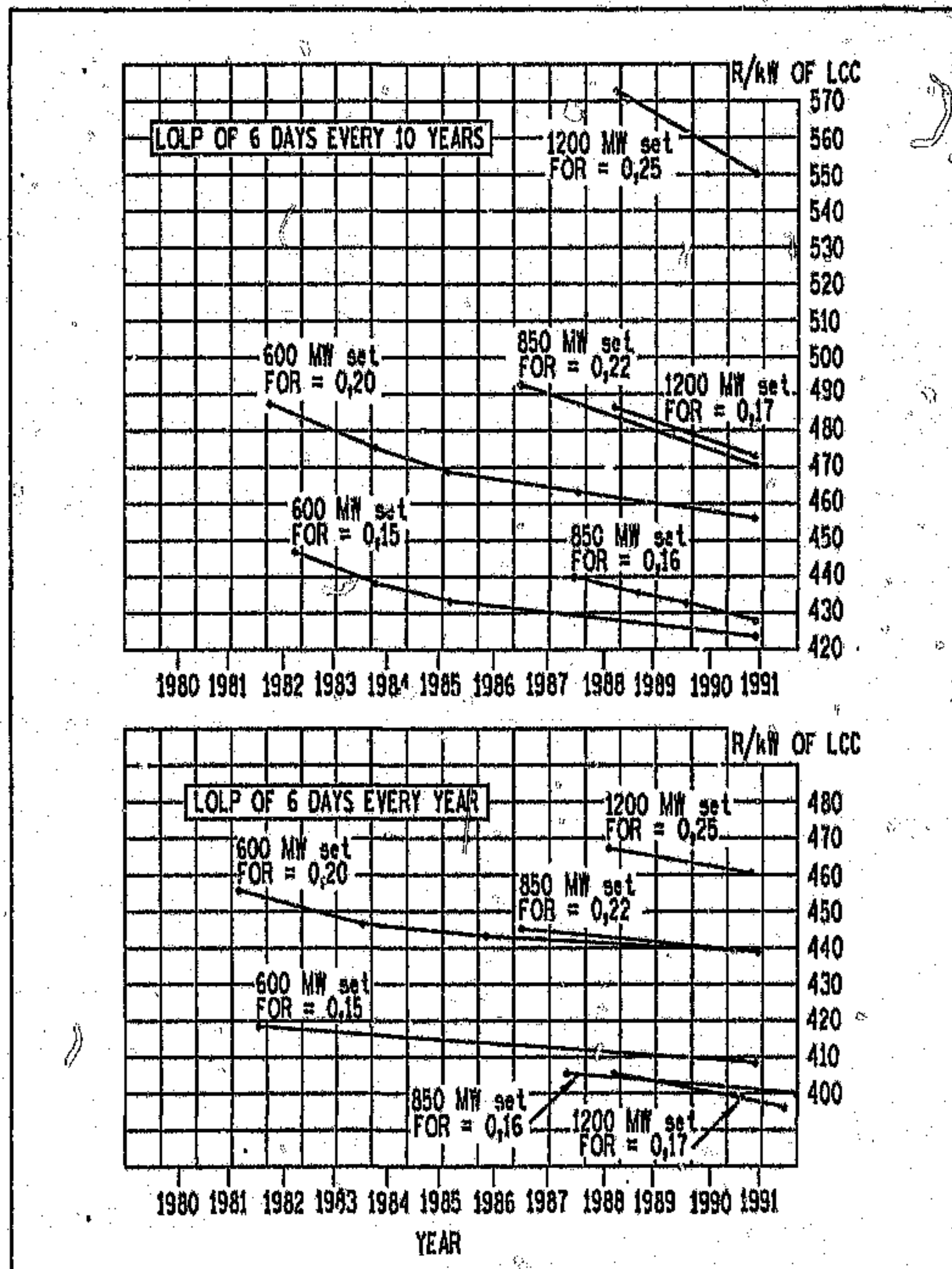

Figure 3-4 Installation Costs Per kW of LCC

the set size will be much reduced if the forced outage rate is low. At the limit, where the forced outage rate is zero the LCC is of course unity regardless of the set size.

Based on this information, it becomes possible to assess the savings achieved through economy of scale with construction costs expressed in Rand per kW of load carrying capability. The following observations regarding coal-fired stations are derived from the graphs shown in Figure 3-4.

(i) With a loss of load probability of six days per year, and considering construction costs alone, the economic set size depends on the level of forced outage rate assumed. For the alternative of forced outage rates of 15 percent applying to the 600 MW sets, 16 percent to the 850 MW sets and 17 percent to the 1 200 MW sets, it is economic to select set sizes larger than 600 MW. On the other hand if the forced outage rates are 20 percent for 600 MW units, 22 percent for 850 MW units and 25 percent for 1 200 MW units, it is equally economic to have 850 or 600 MW sets.

which has a LCC, after allowing for planned maintenance, at least equal to the shortfall.

It is thus interesting to see how the LCC of a generator expressed in percent of its rated output, fluctuates under various circumstances, and how conclusions can be reached for a policy regarding the addition of very large sets in a system. It has been found that the LCC of a proposed new generator will vary as follows:

(i) The LCC of a particular set will be low if the required reliability of supply is high, if the set forced outage rate is high and if its size, in relation to the whole system, (its LCC) is also high.

(ii) There is a non-linear relationship between set size and LCC depending on the number of similar sets already installed. For example, there will be a large LCC improvement over the first, when a second large unit is installed in the system, such as the second set at Koeberg, and a much smaller improvement when, for example the tenth similar unit is installed. Also, the effect of

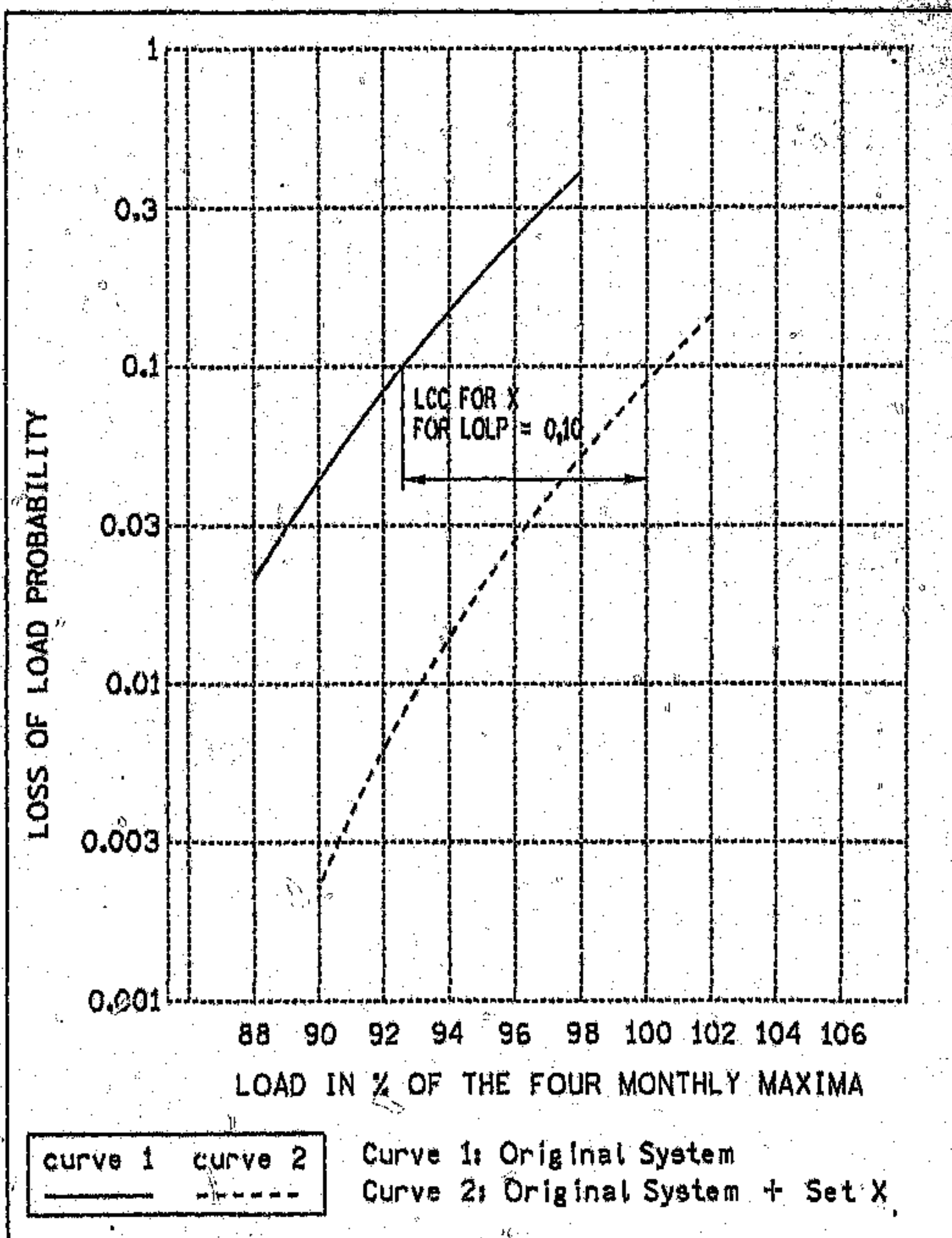

Figure 3-3 System Load Carrying Capability

the system requires to cater for forced outages with a given degree of security of supply.

If a new set is then added to the system of Figure 3-3 and the probability curve recalculated, it is possible to establish what the contribution of that set is to the system with the view of meeting the load at the present level of security of supply. This contribution is known as the "load carrying capability" (LCC) of that particular set if added to that particular system.

3.3.7 Installed capacity

Having established the system demand, the reserve needed for planned maintenance and the LCC of the existing system, the shortfall of capacity in any period can be determined by comparing the LCC of all plant not on planned maintenance with the system maximum demand.

As a year can conveniently be divided in three periods of four months each, the shortfall should normally be examined three times per annum. To retain security of supply this shortfall must be made up by adding plant

$$P = \frac{N!}{r!(N-r)!} F^r (1-F)^{N-r}$$

where: N = number of sets in the station

r = number of sets out of service

F = forced outage rate, per unit.

The probability of r or fewer sets being out is the sum of the probabilities of 0 (zero) to r sets being out and is the same as the probability of N - r or more sets being available.

If each station is treated in this way and the results are combined a curve is obtained which shows the probability of any given amount of power being available for the entire system, as illustrated on Figure 3-3.

If a minimum acceptable level of security of supply is now decided upon, the amount of power which would be available from the system and which would satisfy the desired criteria can be determined from the curve. The difference between this available output and the installed capacity of the system, is the reserve that

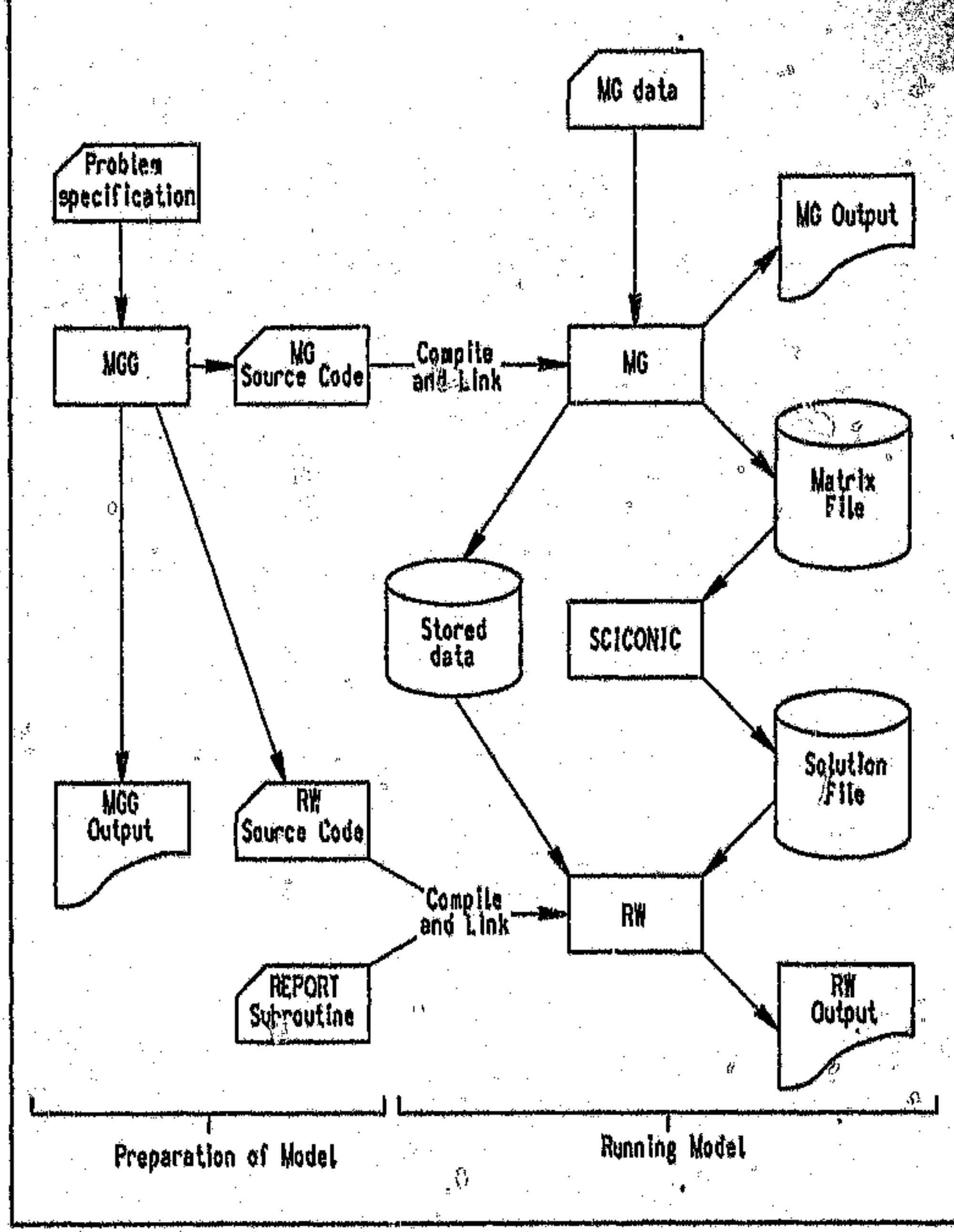

Figure 5-1 Flow Diagram of MGG and SCICONIC

CHAPTER 5

5 THE SOFTWARE USED

The software selected for this project had to run on both the mainframe and workstation environments within the company. Once the formulae had been finalised the development of the simulation package began.

The software packages employed were MGG (Matrix Generator Generator) and Sciconic (optimising software). Figure 5-1 illustrates the steps in the functional flow of the system.

5.1 The MGG Process

Once the formulae had been decided and agreed upon the programming commenced. The first file that had to be created was MGG{filename} DATA and serves as the input file to MGG. The structure of the file will not be discussed here but more information is supplied in appendix C. The formulae were then entered into the file in the required format.

j) Computer performance requirements

- production optimisation run of a full size study should not take longer than one hour on an Apollo,
- expansion optimisation run of a full size study should not take longer than four hours on the mainframe.

k) Documentation

The following is a list of the documentation that was required.

- user manual,
- programmers manual,
- set of test cases,
- a case study for training purposes.

- report on unserved energy (frequency drop, emergency generation, load shedding stages),
- facility to aggregate period data into sub-years data,
- facility to aggregate station data into station group data,
- LOTUS 123 interface,
- graphics package interface,
- optional debug report,
- optional sensitivity report (shadow prices/marginal costs/ranges).

i) General requirements

- a facility to evaluate different scenarios without having to rerun the entire study,
- a facility to use a starting base of a previous run or user-defined,
- the be possibility of to monitoring the progress of the optimisation run by accessing a constantly updating status report should exist,
- running procedures should be menu-driven (as in EGEAS),
- a short day-file should list the major steps and further report only exceptions or abnormalities.

representation could substantially reduce the execution time or turn-over time in the new model for a typical study),

- a facility whereby the constraints which bad to be applied could be specified had to be available,
- a facility had to be provided which would enable the assigning of input-given values to specific input selection of variables,
- decision variables were to be defined as in the Reference Table (appendix A),
- constraints were to be defined as in the Reference Table (appendix A),
- the upper limits of the indices that were required are as tabled below.

Index	Required limit	Old GEX limit
Power source	200	124
Coal source	100	26
Other resource	50	NA
Year	50	30
Period	52	9
Slice	168	99

h) Output facilities

The following were the stipulated output facilities.

- flexible reports in terms of format, level of detail and time steps, few stations or by allocating maintenance the system reserve could be levelized,

- expansion optimisation had to be performed by applying the rolling horizon method, if at all possible,
- an option had to be provided where by a non-economic merit order in the production scheduling could be chosen by applying a set of modified variable operating costs,
- an option had to be provided which would enable the calibration of the load factors of the individual units by progressively derating the capacities (POWRSYM or EGEAS to be used for bench-marking),
- an option where by the decommissioning of stations could be optimised had to be provided.

g) LP formulation

With regards to the LP formulation the following were the requirements

- the adding and modification of equations had to be a relatively simple task which could be performed by an experienced user,
- the Matrix Generator had to allow for possible later introduction of the Z-substitute representation for selected variables (It remained to be tested if this

few stations or by allocating maintenance the system reserve could be levelized,
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- an option had to be provided where by a non-economic merit order in the production scheduling could be chosen by applying a set of modified variable operating costs,
- an option had to be provided which would enable the calibration of the load factors of the individual units by progressively derating the capacities (POWRSYM or EGEAS to be used for bench-marking),
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- Selected reports / graphs / lotus files,
- modular flexible structure designed for easy modification.

e) Input facilities

- data entry via data base system was still under development when Production Planning algorithm was completed,
- data validation and consistency checks had to provide a validation report with different report levels (defaults used, out of normal range, inconsistent with other data, non-fatal error, fatal error etc.), validation required both in interactive and batch mode of operation,
- facility had to be provided which could group units into groups with equivalent properties

f) Optimisation methodology

- weekly load profile had to be represented by a step-wise LDC or a chronological curve,
- LOLP constraint had to be represented by a linear equation,
- maintenance optimisation had to be provided so that by selecting the variable maintenance option for a

b) Software

- Sciconic LP package including matrix generator and report writer for both the IBM and Apollo versions,
- VM operating system on IBM,
- ORACLE relational database package for IBM and Apollo/HP which had already been acquired,
- Graphic package on Apollo/HP,
- All other coding to be written in standard ANSI FORTRAN 77 and to be self-documenting.

c) Interfaces

The interfaces which had to be established had to facilitate proper integration of the different hardware platforms.

- IBM/Apollo bi-directional link for file transfer,
- Apollo/PC hardware link for file transfer,
- Sciconic / report-writer to LOTUS 123 format,
- Sciconic / report-writer to graphical display output.

d) Model structure

- Data entry and data editing,
    - Input Data Base
    - Pre-processor/matrix generator
    - LP package
    - Report Data Base

4.7 Requirements For New Model

The requirements for the of the new model had to cover the following aspects, and are discussed briefly;

- Hardware
- Software
- Interfaces
- Model structure
- Input facilities
- Optimisation methodology
- LP formulation
- General facilities / procedures
- Computer performance requirements
- Documentation

a) Hardware

- IBM for large studies,
- Apollo/HP workstations for smaller studies and data entry.

f) Time horizon and end effects;

- Study horizon covers period of interest,
- Horizon is artificially expanded by N years or to infinity (expansion plan assumed to be frozen at end of study horizon but in the extra years plant at the end of their economic life is replaced by identical plant).

4.6 Generation Expansion Planning Systems

a) Use of models; the following computer programmes were used, by GEP as part of their normal work and in the evaluation phase of this project.

- GEX, EGEAS, POWRSYM, CAPEX, and GENREL[a],
- Output manipulation by LOTUS 123.

b) Computer hardware; the type of computers utilised by GEP were Mainframes (IBM, CDC), minicomputers (HP - Apollo) and PC's.

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a GEX - Old Generation EXpansion Planning programme
EGEAS - Electric Generation , Expansion Planning Analysis System programme (by EPRI)
POWERSYM - Power System Probabilistic Simulation programme
CAPEX - Capital Expenditure programme
GENREL - Generation Reliability programme

c) Treatment of uncertainty;

- Scenario development;
- Cost-benefit analysis of flexibility.

d) Data collection & validation;

- On an annual basis by means of memos or reports,
- Using consistent data sets,
- Using specified formats,
- Manipulation to suit specific problem or model.

e) Load representation;

- Three four-monthly periods of equal weekly peak loads,
- fixed maintenance in each period,
- Weekly Load Duration Curve (LDC) (due to Pump Storage weekly cycle),
- Different winter and summer LDC's,
- Projected Demand Side Management effects incorporated in load forecast,
- Load forecast scenarios.

TR_{ep} TRB_{ep} Transport channel Retirement (pu)

TR_{ey} TRB_{ey}

6.3.3 Resource variables and bounds

$RO_{\&p}$ $ROU_{\&p}$, $[ROL_{\&p}]$ Resource Output (pu)

$RO_{\&y}$ $ROU_{\&y}$, $[ROL_{\&y}]$

$RI_{\&p}$ $RIB_{\&p}$ Resource Installation (pu)

$RI_{\&y}$ $RIB_{\&y}$

$RR_{\&p}$ $RRB_{\&p}$ Resource Retirement (pu)

$RR_{\&y}$ $RRB_{\&y}$

6.4 Definition of Coefficients and Related Calculations

The values of the coefficients are given in the Matrix Generator input data unless otherwise indicated in section 6.4.2(s). Intermediary transformations from the NewGex model input data to the Matrix Generator input data would be done in the NewGex Database.

6.4.1 Definition of coefficients

All coefficients are defined as real (fractional) numbers unless otherwise indicated.

$GUB_{\#p}$

$GR_{\#p}$ $GRB_{\#p}$ Generation Retirement (pu)

6.3.2 Coal variables and bounds

$CO_{\#p}$ Colliery Output (Mt)
$COU_{\#p}$, $[COL_{\#p}]$
$CO_{\#y}$
$COU_{\#y}$, $[COL_{\#y}]$

$TO_{\#p}$ Transport on channel output (Mt)
$[TOU_{\#p}]$, $[TOL_{\#p}]$
$TO_{\#y}$
$[TOU_{\#y}]$, $[TOL_{\#y}]$

$SL_{\#p}$ Stockpile Level at end of period or year (Mt)
$[SLU_{\#p}]$, $[SLL_{\#p}]$

$SL_{\#y}$
$[SLU_{\#y}]$, $[SLL_{\#y}]$

$SI_{\#p}$ Stockpile Input (Mt)
$[SIU_{\#p}]$, $[SIL_{\#p}]$
$SI_{\#y}$
$[SIU_{\#y}]$, $[SIL_{\#y}]$

$SO_{\#p}$ Stockpile Output (Mt)
$[SOU_{\#p}]$, $[SOL_{\#p}]$
$SO_{\#y}$
$[SOU_{\#y}]$, $[SOL_{\#y}]$

$CI_{\#p}$ Colliery Installation (pu)
$CIB_{\#p}$
$CI_{\#y}$
$CIB_{\#y}$

$CR_{\#p}$ Colliery Retirement (pu)
$CRB_{\#p}$
$CR_{\#y}$
$CRB_{\#y}$

$TI_{\#p}$ Transport channel Installation (pu)
$TIB_{\#p}$
$TI_{\#y}$
$TIB_{\#y}$

to section 6.4.2.(b)). In the case of the bounds being defined per slice the values thereof are calculated from period values given in the matrix generator input data.

The coal and resource variables and bounds are defined either on a year basis or on a period basis. The coal and resource constraints are defined accordingly.

Fixed bounds are defined by giving equal lower and upper bounds in the input.

6.3.1 Generation variables and bounds

$GO_{\$s}$	$GOU_{\$s}$,	Generation Output (GW) [$GOL_{\$s}$]
$PL_{\$s}$	$PLU_{\$s}$,	Pumping Load (GW) [$PLL_{\$s}$]
PI_{is}	PIU_{is} ,	Power Import (GW) [PIL_{is}]
PE_{es}	PEU_{es} ,	Power Export (GW) [PEL_{es}]
$PO_{\$p}$		Planned Outage (pu)
RS_{s}	RSU_{s}	Relaxation of Spinning reserve (GW)
$GC_{\$p}$	$GCB_{\$p}$	Generation Common equipment installation (pu)
$GU_{\$p}$		Generation Units installation (pu)

e export (interconnection ...)

y year

p period (including year index)

s slice (including year and period indices)

6.3 Definition Of Variables And Bounds

Some variables are used only for generation expansion planning applications while other variables are only used for production planning applications (refer to Appendix A).

In appendix "A" the upper bound names are composed of the variable name and the letter 'U'. Lower bound names are composed of the variable name and the letter 'L'. Bivalent bound names are composed of the variable name and the letter 'B'. Optional bounds are indicated by [].

In most cases the values of the bounds are given directly in the input data. Otherwise the values of the bounds are calculated from the coefficients (refer

- some variables, bounds and coefficients, which only apply to the expansion planning phase of this project, are tentatively included in this chapter but would be revised later on.

6.2 Indices

The indices associated with the variables and constraints that were used in the definition of the LP solution are defined in this section. A variable and or a constraint can have any of the indices listed below as an index or combination of indices.

$ power source
(power station ...)

coal source or in general
any resource linked to a transport channel
(interconnected colliery, open market, water ...)

& other resource not linked to a transport channel
(isolated colliery, nuclear fuel, manpower, finance, environment ...)

@ transport channel linking coal source and power source; multiple links between same sources may be defined (conveyor belt, trucks ...)

i import
(cogeneration ...)

ITEMS REQUIRED	MAXIMUM NUMBER REQUIRED	SYSTEM IMPOSED LIMITS
Years in study period	36	36
Periods in year	52	360
Periods in study period	360	360
Slices in period	168	360
Power stations - including import and export	200	360
Collieries	100	360
Resources	100	360
Constraints	16000	16000
Constraints and variables	32000	32000
Unique values	32000	32000

To facilitate extra-long-range generation expansion planning an alternative version in which the maximum number of years in a study period could be increased to 50 and the maximum number of periods in a year could be decreased to 36 was to be provided.

6.1.3 Special Aspects

Special modelling aspects that were considered,

- the matrix partitioning of the production planning system was to be implemented in the expansion planning phase of this project.
- fixed operating costs are not a primary consideration in production planning and would only be defined in the expansion planning phase of this project.

6.1.1 Differences to formulation of old GEX model

The following is a listing of the differences between the old GEX programme and those of NewGex;

- calibration of unit availability instead of worst case equations
- Z-substitute formulation not used
- transport routes are defined between collieries and stations instead of between stations
- choice between period or year equations and decision variables for coal and other resources
- additional resource equations
- coal stockpile modelling

6.1.2 Dimensions

The limits required to enable adequate modelling and the hard limits imposed by the LP formulation are listed.

CHAPTER 6

6 FORMULATION OF THE PRODUCTION SCHEDULING SYSTEM

6.1 General

This chapter contains in a concise form all the necessary information about the LP-formulation of the production scheduling sy tem of the NewGex model. During the development of the Matrix Generator Programme this chapter was continuously updated. The deferent points covered in this chapter are;

- Differences in formulation to the old GEX model,
- Indices used in the formulae,
- Variables and bounds for the different aspects of generation, coal and resources,
- Definition of coefficients and related calculations,
- Definition of generation, coal and resource constraints,
- Finally, the establishing of the objective function and the cost contributions from generation, coal and resources.

5.4.2 Matrix Size Limit

The settings for the size of matrix can be changed without much difficulty provided that the limits of both MGG and Sciconic are not violated. The limits of these two packages are not more than 32 768 rows plus columns plus ranges.

5.4 Problems Encountered

The incremental approach was used in developing the programme. First the parameters were defined and then each equation was implemented in turn. After that, a series of simple tests were done, i.e. a simple report writer was used that just showed that the equations were being satisfied. The PRINTRANGE option was not considered at this stage. Once all the equations had been implemented the focus shifted to the report writer.

5.4.1 Obstacles in developing the report writer

It was with some relief that it was found out that Sciconic had the facility to calculate the ranges over which a shadow price is effective. This however did not solve the whole problem. The only way that this information could be obtained was to dump the information onto a flat file and read it in as data. This was all well and good until a redundant constraint was present and instead of a range being given, "-INFINITY" (negative infinity) or "+INFINITY" (positive infinity) was given as the range. Extra FORTRAN code had to be generated to solve this problem.

'PRINTRANGE' enables one to do the ranging of the matrix to ascertain over which ranges the shadow price is effective. The output of Sciconic is stored in a file which can only be read by the compiled report writer. A separate report writer had to be developed to process this output.

5.3 The Report Writer

The report writer could only be written in FORTRAN, illustrated in appendix E. The common blocks produced, in the form of files, by both RUNMGG and Sciconic had to be included. By using the common blocks the necessary information regarding the optimised matrix could be written out in any specified format.

Access to the ranges, over which optimality was achieved, was a little more complicated. This was achieved by printing the ranges to a data file and the file was later opened in the report writer and processed.

The RUNMGG command was executed next which checked the input format of the MGG file and produces the Matrix Generator. It also sets out the format in which the input data was to be processed, illustrated in appendix D. An additional set of files was created for later used in the report writer. The MGG file being correct, the MGCL command is executed to compile and link the matrix generator. Using the prescribed format RUNMG was executed. The output from this operation produced the matrix file which standard 'MPS' format. This is the file to be used by the optimiser.

5.2 The Optimiser - Sciconic

Sciconic is a separate mathematical programming package and need not be used in connection with MGG provided that the input format conforms to the 'MPS' format standard. By issuing a series of commands the matrix is loaded and optimised.

Two of the commands that may be used while running Sciconic are 'PRINTSOLN' and 'PRINTRANGE'. The 'PRINTSOLN' instruction enables one to view at the solution and by specifying certain options one can look at specific sections of the matrix solution.

6.5.1 (i) Energy export lower bound

EEL (e,y,[p]) [GWh]

for selected power exports in each selected period and/or year

$$PLW_p * \sum_{s \in p} (PE_{es} * SWH_s) \geq EEL_{ep}$$

and/or

$$\sum_{p \in y} (PLW_p * \sum_{s \in p} (PE_{es} * SWH_s)) \geq EEL_{ey}$$

Energy Exported	≥	Energy Lower Bound

The energy of a selected power export cannot be less than the energy lower bound.

6.5.1 (h) Energy export upper bound

EEU (e,y,[p]) [GWh]

for selected power exports in each selected period and/or year

$$PLW_p * \sum_{s \in p}(PE_{es} * SWH_s) \leq EEU_{ep}$$

and/or

$$\sum_{p \in y} (PLW_p * \sum_{s \in p} (PE_{es} * SWH_s)) \leq EEU_{ey}$$

$$\underset{\text{Exported}}{\text{Energy}} \leq \underset{\text{Upper Bound}}{\text{Energy}}$$

The energy of a selected power export can not exceed the energy upper bound.

6.5.1 (g) Energy import lower bound

EIL (i, y, [p]) [GWh]

for selected power import sources in each selected period and/or year

$$PLW_p * \sum_{s \in p} (PI_{is} * SWH_s) \geq EIL_{ip}$$

and/or

$$\sum_{p \in y} (PLW_p * \sum_{s \in p} (PI_{is} * SWH_s)) \geq EIL_{iy}$$

Energy Imported	≥	Energy Lower Bound

The energy imported by a selected power source cannot be less than the energy lower bound.

6.5.1 (f) Energy import upper bound

EIU (i,y,[p]) [GWh]

for selected power import sources in each selected period and/or year

$$PLW_p * \sum_{s \in p} (PI_{is} * SWH_s) \leq EIU_{ip}$$

and/or

$$\sum_{p \in y} (PLW_p * \sum_{s \in p} (PI_{is} * SWH_s)) \leq EIU_{iy}$$

Energy Imported	≤	Energy Upper Bound

The energy imported by a selected power source cannot exceed the energy upper bound.

6.5.1 (e) Pumped storage balance

PSB ($,y,p) [GWh]

for each pumped storage station

$$\sum_{s \in P} (GO_{\$s} * SWH_s) - \sum_{s \in P} (PL_{\$s} * SWH_s * EFF_{\$p}) = PSI_{\$p}$$

Total Energy Generated	-	Total Energy of Water Pumped	=	Energy of Net Water Inflow

The total energy generated by the pumped storage station must be equal to the total pumping energy multiplied by the cycle efficiency plus the generation energy available from the net water inflow into the upper reservoir. The time span of this equation is one week.

The energy produced by a selected power station cannot be less than the energy lower bound.

6.5.1 (d) Planned outage balance

POB ($,y) [puh]

for selected power stations in each selected year

$$\boxed{\sum_{P \in Y} (PO_{\$p} * PLW_p) = POR_{\$y} * \sum_{P \in Y} PLW_p}$$

Sum of Variable POR	*	Period Length	=	Average POR	*	Sum of Period Lengths

The weighted average of the variable planned outage must be equal to the average planned outage.

6.5.1 (b) Generation energy upper bound

GEU ($,y,[p])   [GWh]

for each hydro station and for other selected power stations in each selected period and/or year

$$PLW_p * \sum_{s\in p} (GO_{\$s} * SWH_s) \leq GEU_{\$p}$$

and/or

$$\sum_{p\in q} (PLW_p * \sum_{s\in p} (GO_{\$s} * SWH_s)) \leq GEU_{\$y}$$

Energy Generated	≤	Energy Upper Bound

The energy produced by a selected power station can not exceed the energy upper bound.

6.5.1 (c)   Generation Energy Lower Bound

GEL ($,y,[p])   [GWh]

for selected power stations in each selected period and/or year

$$PLW_p * \sum_{s\in p} (GO_{\$s} * SWH_s) \geq GEL_{\$p}$$

and/or

$$\sum_{p\in y} (PLW_p * \sum_{s\in p} (GO_{\$s} * SWH_s)) \geq GEL_{\$y}$$

Energy Generated	≥	Energy Lower Bound

the output generated at all the power stations plus the total power imported minus the energy required for pumping at all the pump storage stations minus all the power exported plus the relaxation on spinning reserve must be equal to the consumer demand.

6.4.2 (b) Calculation of bound values

- Upper bound on generation output

$$GOU_{\$s} = ADF_{\$s} * (1 - POR_{\$p}) * (1 - FOR_{\$p}) * IGC_{\$p}$$

- Upper bound on pumping load

$$PLU_{\$s} = ADF_{\$s} * (1 - POR_{i}) * (1 - FOR_{\$p}) * IPC_{\$p}$$

6.5 Definition Of Constraints

Some constraints are used only for generation expansion planning applications while other constraints are only used for production planning applications (refer to Appendix A).

The coal and resource constraints are defined either on a yearly basis or on a period basis. Coal and resource variables and bounds are defined accordingly.

6.5.1 Generation constraints

6.5.1 (a) Generation load balance

GLB (y,p,s) [GW]

for each slice in the study

$$\boxed{\sum_{\$} GO_{\$s} + \sum_{i} PI_{is} - \sum_{\$} PL_{\$s} - \sum_{e} PE_{es} + RS_{s} = DMC_{s}}$$

Generation Output	+	Power Import	-	Pumping Load	-	Power Export	+	Relax. Spin. Res.	=	Demand

$REF_{\$p}$	Resource efficiency (excluding auxiliaries) (resource units / GWh)
$RAX_{\$p}$	Auxiliary resource consumption at no load (pu)
SWH_{s}	Slice width (hrs)
$SLI_{e\$}$	Initial stockpile level (Mt)

6.4.2 Related calculations

6.4.2 (a) Calculation of coefficients

- Availability derating factor

$ADF_{\$s}$ = to be defined by the user of the system.

Heuristic methods to determine an appropriate availability derating factor would be fully evaluated in the testing phase of this project. For the time being this availability derating factor has been assumed to be equal to 1.

- Demand of consumers

DMC_{s} = load level in slice * weekly peak * annual peak

	coefficient could be negative if the water outflow exceeds water inflow.
$POR_{\$y}$	The average planned outage rate used in the planned outage balance equation (pu)
$POR_{\$p}$	The planned outage rate (pu)
$QGO_{\$p}$	Variable Operating & Maintenance cost (Rm/GWh)
QPI_{ip}	Power Import cost (Rm/GWh)
$QPE_{@p}$	Power Export income (Rm/GWh)
$QGC_{\$p}$	Generation Common equipment cost (Rm/GW)
$QGU_{\$p}$	Generation Unit cost (Rm/GW)
$QCO_{\#p}$ $QCO_{\#y}$	Colliery variable output cost (Rm/Mt)
$QSL_{@p}$ $QSL_{@y}$	Stockpile level cost (Rm/Mt)
$QSI_{@p}$ $QSI_{@y}$	Stockpile input cost (Rm/Mt)
$QSO_{@p}$ $QSO_{@y}$	Stockpile output cost (Rm/Mt)
$QTX_{@p}$ $QTX_{@y}$	Transport cost on channel (Rm/Mt)
$QCI_{\#p}$ $QCI_{\#y}$	Colliery Installation cost (Rm/Mt)
$QTI_{@p}$ $QTI_{@y}$	Transport Channel Installation cost (Rm/pu)
$QRO_{\&p}$ $QRO_{\&y}$	Resource Output cost (Rm/pu)
$QRI_{\&p}$ $QRI_{\&y}$	Resource Installation cost (Rm/pu)
QR[illegible]$_{\&p}$	Spinning Reserve Relaxation cost (Rm/pu)

$ADF_{\$s}$	Availability derating factor (pu)
$AUX_{\$p}$ (pu)	Auxiliary coal consumption at no load
$CVL_{\#p}$ $CVL_{\#y}$	The calorific value of coal from colliery # (TJ/Mt)
$CVR_{@p}$ $CVR_{@y}$	The calorific value reduction factor from stockpile @ (pu)
DMC_{s}	Demand of consumers (GW)
$EFF_{\$p}$	Station efficiency (excluding auxiliaries) or cycle efficiency for pumped storage stations (pu)
EIU_{ip} EIU_{iy}	Energy import upper bound (GWh)
EIL_{ip} EIL_{iy}	Energy import lower bound (GWh)
EEU_{ep} EEU_{ey}	Energy export upper bound (GWh)
EEL_{ep} EEL_{ey}	Energy export lower bound (GWh)
$FOR_{\$p}$	Forced outage rate (pu)
$GEU_{\$p}$ $GEU_{\$y}$	Generation energy upper bound (GWh)
$GEL_{\$p}$ $GEL_{\$y}$	Generation Energy lower bound (GWh)
$IGC_{\$p}$	Installed generation sent-out capacity (GW), (excluding mothballed capacity or reserve storage)
$IPC_{\$p}$	Installed pumping capacity (GW)
PLW_{p}	Period length (weeks)
$PSI_{\$p}$	The energy which can be generated from the net water inflow into the upper reservoir in one week (GWh). This

The input structures and report layouts, illustrated in appendices D and F respectively, were developed in parallel with the programming of the formulae but were customised to simplify inputting of data and reading of reports. This included the presentation of sensitivity analysis data. In establishing the input and output formats it was necessary to keep in mind that a GEP database would be used in future to create the relevant inputs, and that a similar database would possibly capture the output to enable easier comparisons to be performed.

Final acceptance occurred only once a thorough evaluation of the production planning module had been performed. This required that the customer test a number of scenarios to ensure that all potential problems and computer "bugs" had been removed. This step could have delayed the project as the customer could not give the required attention to the evaluation of the programme. Fortunately, the Production Planning and Internal Tariff division of Transmission Group, required the use of NewGex. This resulted in the speeding up of the section of the project. In the evaluation of NewGex a number of requests were received

Having adopted an incremental approach, it implied that for each specific stage of the production planning project, work which had been completed was thoroughly tested before proceeding further. As a result of this methodology implementation time was substantially reduced. This was achieved by adopting the following four steps in developing the computer algorithm;

- establishing the relevant formulae,
- setting up the input structures and layouts,
- setting up the reporting structures, and
- determining the correctness of calculations and acceptance of the above three interfaces.

In the formulation of the production planning section of NewGex the formulae utilised were agreed to by the customer, GEP, before any computer programming was undertaken. In developing the programme a number of test cases were compiled to ensure that each formula implemented operated within the required limitations. This was carried out systematically to ensure that no anomalies occurred due to interactions between formulae.

Establishing the user's requirements and needs revealed that the LP studies performed by the customers, GEP and PP&IT, fell broadly into the following areas;

a) The evaluation of alternative production plans.

b) Expansion plan optimisation.

c) Long-term budget exercises.

In analysing the requirements it became clear that the model should be developed incrementally, allowing the work achieved at each milestone to be used as a production tool. Thus it was agreed that the production planning function, as the most pressing need, would be the first increment to be developed and would serve as the foundation upon which the rest of the NewGex function would be built.

As a result, this report has primarily focused upon the production planning section of the NewGex project. However, other requirements, formulae and relevant aspects deemed necessary have been documented to achieve a holistic view of the problem.

CHAPTER 7

7 CONCLUSION

This report has documented the process of developing the production planning element of the NewGex Linear Programming (NLP) function. The user's requirements, for this section of the NLP function, have been successfully achieved and the system is currently being utilised by Generation Expansion Planning Division (GEP) and Production Planning & Internal Tariff (PP&IT) Division within Eskom's Transmission Group.

To establish an understanding of the various applications of Linear Programming (LP) a literature survey was carried out. This exercise revealed the history of LP and that LP had been put to use in the power utility industry, for modelling purposes, as early as the late 1950s. An overview of this work was conducted and documented, by the author, forming the basis from which NewGex was developed. This included a thorough analysis of the existing linear programming function within Eskom, i.e. the LP function "GEX".

6.6.2 Coal Costs

$$+ \sum_{\#} (QCO_{\#p} * CO_{\#p}) + \sum_{\#} (QCO_{\#y} * CO_{\#y})$$

Colliery Variable Output cost

$$+ \sum_{\#} (QCI_{\#p} * CI_{\#p}) + \sum_{\#} (QCI_{\#y} * CI_{\#y})$$

Colliery Installation cost

$$+ \sum_{@} (QSL_{@p} * SL_{@p}) + \sum_{@} (QSL_{@y} * SL_{@y})$$

Stockpile Level cost

$$+ \sum_{@} (QSI_{@p} * SI_{@p}) + \sum_{@} (QSI_{@y} * SI_{@y})$$

Stockpile Input cost

$$+ \sum_{@} (QSO_{@p} * SO_{@p}) + \sum_{@} (QSO_{@y} * SO_{@y})$$

Stockpile Output cost

$$+ \sum_{@} (QTX_{@p} * TO_{@p}) + \sum_{@} (QTX_{@y} * TO_{@y})$$

Coal Transport cost on channel

$$+ \sum_{@} (QTI_{@p} * TI_{@p}) + \sum_{@} (QTI_{@y} * TI_{@y})$$

Transport Channel Installation cost

6.6.3 Resource Costs

$$+ \sum_{\&} (QRO_{\&p} * RO_{\&p}) + \sum_{\&} (QRO_{\&y} * RO_{\&y})$$

Resource Variable Output cost

$$+ \sum_{\&} (QRI_{\&p} * RI_{\&p}) + \sum_{\&} (QRI_{\&y} * RI_{\&y})$$

Resource Installation cost

6.6 Objective Function

The objective function needs to be minimised. All the cost coefficients are named according to the variables and are preceded by the letter 'Q'. All the following terms in the objective function apply to all relevant periods and years and are expressed in millions of Rand.

6.6.1 Generation Costs

$$+ \sum_{p \in Y} \sum_{\$} \{QGO_{\$p} * PLW_p * \sum_{s \in P} (GO_{\$s} * SWH_s)\}$$

Variable O&M cost

$$+ \sum_{p \in Y} \sum_{i} \{QPI_{ip} * \text{[illegible]} * \sum_{s \in P} (PI_{is} * SWH_s)\}$$

Power Import cost

$$- \sum_{p \in Y} \sum_{e} \{QPE_{ep} * PLW_p * \sum_{s \in P} (PE_{es} * SWH_s)\}$$

Power Export income

$$- \sum_{p \in Y} \{QRS_p * PLW_p * \sum_{s \in P} (RS_s * SWH_s)\}$$

Relaxation of the spinning reserve

$$+ \sum_{p \in Y} \sum_{\$} (QGC_{\$p} * GC_{\$p})$$

Generation Common equipment cost

$$+ \sum_{p \in Y} \sum (QGU_{\$p} * GU_{\$p})$$

Generation Unit cost

6.5.3 Resource Constraints

6.5.3 (a) Resource transfer balance

RTB (&, $, y, [p]) [pu]

for each selected resource

for each period in each year

or

for each year

$$RO_{\&p} - PLW_p * \sum_{s \in p} (GO_{\$s} * SWH_s / REF_{\$p}) = PLW_p * \sum_{s \in p} (SWH_s * RAX_{\$p} * IGC_{\$p})$$

or

$$RO_{\&y} - \sum_{p \in y} (PLW_p * \sum_{s \in p} (GO_{\$s} * SWH_s / REF_{\$p})) = \sum_{p \in y} (PLW_p * \sum_{s \in p} (SWH_s * RAX_{\$p} * IGC_{\$p}))$$

Resource Supplied to a Power Station	-	Resource and Auxiliary Requirement at a Power station	=	0

Resource and auxiliary requirements at a power station must be equal to the resource supplied to the power station.

6.5.2 (c) Stockpile balance

SPB (@,$,y,[p]) [Mt]

for each selected stockpile
for each period in each year
or
for each year

$$SI_{sp} - SO_{sp} + SL_{s(p-1)} - SL_{sp} = 0$$

or

$$SI_{sy} - SO_{sy} + SL_{s(y-1)} - SL_{sy} = 0$$

Net Stockpile Input	-	Increase in Stockpile Level	=	0

The stockpile input minus the stockpile output must be equal to the increase in stockpile level.

Note : For the first period or year the variable $SL_{s(p-1)}$ or $SL_{s(y-1)}$ is not a variable but a coefficient (SLI_s).

6.5.2 (b) Coal transfer balance

CTB (#,y,[p]) [Mt]

for each colliery

for each period in each year

or

for each year

$$CO_{\#p} - \sum_{@} TO_{@p} = 0$$

or

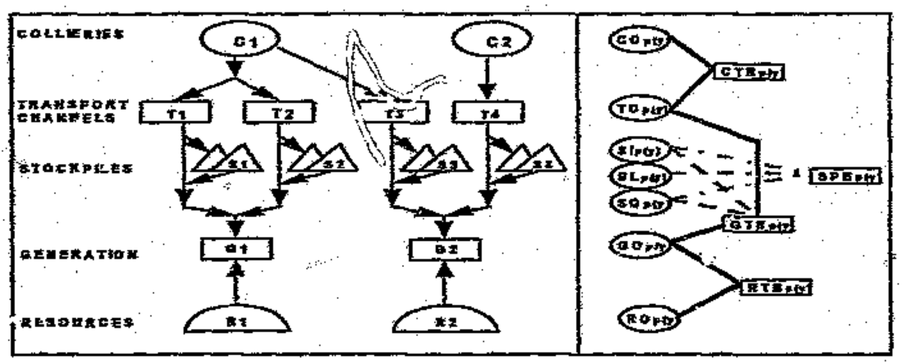
$$CO_{\#y} - \sum_{@} TO_{@y} = 0$$

Colliery Output	-	Total Coal Transported	=	0

The output of a colliery must be equal to the total coal transported from the colliery on three possible channels to various stations.

Illustration 6-1

COLLIERY - TRANSPORT - STOCKPILE - GENERATION - RESOURCE - NETWORK ILLUSTRATION



Note: In a particular study the decision variables CO, TO, SI,SL,SO and RO will ether all be defined per period or per year.
In the first case optional constraints are allowed to put upper and lowe bounds on the aggregated annual output ($\Sigma\ CO_p <=> k, \Sigma\ RO_p <=> k$)

$$PLW_p * \sum_{\$ \in p} (GO_{\$s} * SWH_s / EFF_{\$p})$$

$$- \sum_{@}(TO_{@p} * CVL_{\#p} / 3.6)$$

$$+ \sum_{@}(SI_{@p} * CVL_{\#p} / 3.6)$$

$$- \sum_{@}(SO_{@p} * CVR_{@p} * CVL_{\#p} / 3.6)$$

$$= - PLW_p * \sum_{\$ \in p} (SWH_s * AUX_{\$p} * IGC_{\$p})$$

or

$$\sum_{p \in Y} (PLW_p * \sum_{\$ \in p} (GO_{\$s} * SWH_s / EFF_{\$p}))$$

$$- \sum_{@}(TO_{@y} * CVL_{\#y} / 3.6)$$

$$+ \sum_{@}(SI_{@y} * CVL_{\#y} / 3.6)$$

$$- \sum_{@}(SO_{@y} * CVR_{\#y} * CVL_{\#y} / 3.6)$$

$$= - \sum_{p \in Y} (PLW_p * \sum_{\$ \in p} (SWH_s * AUX_{\$p} * IGC_{\$p}))$$

Energy Requirement incl. Aux. Power at a Power Station	-	Energy Transported to a Power Station	-	Energy of Coal from Stockpile	=	0

The heat value of the energy required at a power station including auxiliary power must be equal to the total heat value of the energy of the coal transported over the different routes to the power station and taken from the stockpiles. The interrelationship between collieries, transport channels, stockpiles and power stations is illustrated in Illustration 6-1.

6.5.2 Coal constraints

6.5.2 (a) Generation transfer balance

GTB ($,y,[p]) [GWh]

for each selected power station
for each period in each year
or
for each year

```
C**       U=5  STOCKPILE INPUT LOWER BOUND  (SIL)
C**       U=6  STOCKPILE INPUT COST  (QSI)
C**       U=7  STOCKPILE OUTPUT UPPER BOUND  (SOU)
C**       U=8  STOCKPILE OUTPUT LOWER BOUND  (SOL)
C**       U=9  STOCKPILE OUTPUT COST  (QSO)
 STPY  (C,G,Y,U)   (2X,F6.4)
C
C**       STPP  *** STOCKPILE PERIOD DATA ***
C**       U=1  STOCKPILE LEVEL UPPER BOUND (SLU)
C**       U=2  STOCKPILE LEVEL LOWER BOUND(SLL)
C**       U=3  STOCKPILE LEVEL COST (QSL)
C**       U=4  STOCKPILE INPUT UPPER BOUND (SIU)
C**       U=5  STOCKPILE INPUT LOWER BOUND(SIL)
C**       U=6  STOCKPILE INPUT COST (QSI)
C**       U=7  STOCKPILE OUTPUT UPPER BOUND (SOU)
C**       U=8  STOCKPILE OUTPUT LOWER BOUND(SOL)
C**       U=9  STOCKPILE OUTPUT COST (QSO)
 STPP  (C,G,Y,P,U)   (2X,F6.4)
C
C-----------------------------------------------------------------------
C**       RESG  *** RESOUCE GENERAL DATA ***
C**       J=1
 RESG  (R,J)   (2X,A4)
C
C**       RESY  *** RESOUCE YEAR DATA ***
C**       L=1  RESOURCE OUTPUT UPPER BOUND  (ROU)
C**       L=2  RESOURCE OUTPUT LOWER BOUND  (ROL)
C**       L=3  RESOURCE OUTPUT COST  (QRO)
 RESY  (R,Y,L)   (2X,F6.4)
C
C**       RESP  *** RESOUCE PERIOD DATA ***
C**       L=1  RESOURCE OUTPUT UPPER BOUND  (ROU)
C**       L=2  RESOURCE OUTPUT LOWER BOUND  (ROL)
C**       L=3  RESOURCE OUTPUT COST  (QRO)
 RESP  (R,Y,P,L)   (2X,F6.4)
C
C*********1*********2*********3*************************************
C
INTERNAL VALUES
C
C
C  **********
C       CALCULATE DEMAND IN SLICE AND SLICE WIDTH
C
C      SWH  *** WIDTH OF SLICE***
 SWH  (Y,P,S)
C
C      DMCS  *** DEMAND OF CONSUMER***
 DMCS  (Y,P,S)
C
C      PLW  *** PERIOD LENGTH WEEKS ***
C         K = 1 : PLW
C         K = 2 : THE SUM OF SWH IN PERIOD
 PLW  (Y,P,K)
C
C      SUMPLW   *** PART OF COEFFICIENT "PO2"            ***
C               *** PLANNED OUTAGE BALANCE CONSTRAINT    ***
C
C      SUMGT5   *** COEFFICINT "5" OF GENERATION ***
C               *** TRANSFER BALANCE CONSTRAINT  ***
C
```

```
 TCXG   (C,J)     (2X,F6.4)
C
C**       TCXY  *** TRANSPORT ON CHANNEL 'X' YEAR DATA ***
C**       L=1  TRANSPORT CHANNEL 'X' UPPER BOUND (TXU)
C**       L=2  TRANSPORT CHANNEL 'X' LOWER BOUND(TXL)
C**       L=3  TRANSPORT COST ON CHANNEL (QTX)
 TCXY   (C,G,Y,L)    (2X,F6.4)
C
C
C**       TCXP  *** TRANSPORT ON CHANNEL 'X' PERIOD DATA ***
C**       L=1  TRANSPORT CHANNEL 'X' UPPER BOUND (TXU)
C**       L=2  TRANSPORT CHANNEL 'X' LOWER BOUND (TXL)
C**       L=3  TRANSPORT COST ON CHANNEL (QTX)
 TCXP   (C,G,Y,P,L)    (2X,F6.4)
C
C-----------------------------------------------------------------
C**       TCYG  *** TRANSPORT ON CHANNEL 'Y' GENERAL DATA ***
C**       J=1
 TCYG   (C,J)     (2X,F6.4)
C
C**       TCYY  *** TRANSPORT ON CHANNEL 'Y' YEAR DATA ***
C**       L=1  TRANSPORT CHANNEL 'Y' UPPER BOUND (TYU)
C**       L=2  TPANSPORT CHANNEL 'Y' LOWER BOUND(TYL)
C**       L=3  TRANSPORT COST ON CHANNEL (QTY)
 TCYY   (C,G,Y,L)    (2X,F6.4)
C
C
C**       TCYP  ***(.RANSPORT ON CHANNEL 'Y' PERIOD DATA ***
C**       L=1  TRANSPORT CHANNEL 'Y' UPPER BOUND (TYU)
C**       L=2  TRANSPORT CHANNEL 'Y' LOWER BOUND (TYL)
C**       L=3  TRANSPORT COST ON CHANNEL QKTY)
 TCYP   (C,G,Y,P,L)    (2X,F6.4)
C
C-----------------------------------------------------------------
C**       TCZG  *** TRANSPORT ON CHANNEL 'Z' GENERAL DATA ***
C**       J=1
 TCZG   (C,J)     (2X,F6.4)
C
C**       TCZY  *** TRANSPORT ON CHANNEL 'Z' YEAR DATA ***
C**       L=1  TRANSPORT CHANNEL 'Z' UPPER BOUND (TZU)
C**       L=2  TRANSPORT CHANNEL 'Z' LOWER BOUND(TZL)
C**       L=3  TRANSPORT COST ON CHANNEL (QTZ)
 TCZY   (C,G,Y,L)    (2X,F6.4)
C
C
C**       TCZP  *** TRANSPORT ON CHANNEL 'Z' PERIOD DATA ***
C**       L=1  TRANSPORT CHANNEL 'Z' UPPER BOUND (TZU)
C**       L=2  TRANSPORT CHANNEL 'Z' LOWER BOUND (TZL)
C**       L=3  TRANSPORT COST ON CHANNEL (QTZ)
 TCZP   (C,G,Y,P,L)    (2X,F6.4)
C
C-----------------------------------------------------------------
C**       STPG  *** STOCKPILE GENERAL DATA ***
C**       J=1  INITIAL STOCKPILE LEVEL  (SLI)
 STPG   (C,G,J)    (2X,F6.4)
C
C**       STPY  *** STOCKPILE YEAR DATA ***
C**       U=1  STOCKPILE LEVEL UPPER BOUND   (SLU)
C**       U=2  STOCKPILE LEVEL LOWER BOUND   (SLL)
C**       U=3  STOCKPILE LEVEL COST  (QSL)
C**       U=4  STOCKPILE INPUT UPPER BOUND   (SIU)
```

```
C**       K=1 ENERGY IMPORT UPPER BOUND   (EIU)  (GWH)
C**       K=2 ENERGY IMPORT LOWER BOUND   (EIL)  (GWH)
 PIMY   (I,Y,K)     (2X,F6.4)
C
C**       PIMP   *** POWER IMPORT PERIOD DATA ***
C**       N=1  POWER IMPORT UPPER BOUND   (PIU)
C**       N=2  POWER IMPORT LOWER BOUND   (PIL)
C**       N=3  COST OF POWER IMPORT   (QPI)
C**       N=4  ENERGY IMPORT UPPER BOUND   (EIU)  (GWH)
C**       N=5  ENERGY IMPORT LOWER BOUND   (EIL)  (GWH)
 PIMP   (I,Y,P,N)     (2X,F6.4)
C
C
C------------------------------------------------------------------------------
C
C**       PEXG   *** POWER EXPORT GENERAL DATA ***
C**       J=1
 PEXG   (E,J)     (2X,F6.4)
C
C
C**       PEXY   *** POWER EXPORT YEAR DATA ***
C**       K=1 ENERGY EXPORT UPPER BOUND   (EEU)  (GWH)
C**       K=2 ENERGY EXPORT LOWER BOUND   (EEL)  (GWH)
 PEXY   (E,Y,K)     (2X,F6.4)
C
C**       PEXP   *** POWER EXPORT PERIOD DATA ***
C**       T=1  POWER EXPORT UPPER BOUND   (PEU)
C**       T=2  POWER EXPORT LOWER BOUND   (PEL)
C**       T=3  COST OF POWER EXPORT   (QPE)
C**       T=7  ENERGY EXPORT UPPER BOUND   (EEU)  (GWH)
C**       T=8  ENERGY EXPORT LOWER BOUND   (EEL)  (GWH)
 PEXP   (E,Y,P,T)     (2X,F6.4)
C
C
C
C*********1*********2*********3*************************************************
C**       COLG   *** COLLIERY GENERAL DATA ***
C**       J=1
 COLG   (C,J)     (2X,F6.4)
C
C**       COLY   *** COLLIERY YEAR DATA ***
C**       N=1  COLLIERY OUTPUT UPPER BOUND (COU)
C**       N=2  COLLIERY OUTPUT LOWER BOUND(COL)
C**       N=3  COLLIERY OUTPUT COST (QCO)
C**       N=4  CALORIFIC VALUE   (CVL)   (MJ/KG)
C**       N=5            CVR
 COLY   (C,Y,N)     (2X,F6.4)
C
C
C**       COLP   *** COLLIERY PERIOD DATA ***
C**       N=1  COLLIERY OUTPUT UPPER BOUND (COU)
C**       N=2  COLLIERY OUTPUT LOWER BOUND (COL)
C**       N=3  COLLIERY OUTPUT COST (QCO)
C**       N=4  CALORIFIC VALUE   (CVL)   (MJ/KG)
C**       N=5       CVR
 COLP   (C,Y,P,N)     (2X,F6.4)
C
C
C------------------------------------------------------------------------------
C**       TCXG   *** TRANSPORT ON CHANNEL 'X' GENERAL DATA ***
C**       J=1
```

```
C**       SYSY  *** SYSTEM YEAR DATA ***
C**       K=1 THE LOAD PEAK FOR THE YEAR  (GW)
C**       K=2 THE WEEKLY MAXIMA CURVE
 SYSY  (Y,K)     (2X,F6.4)
C
C
C**       SYSP  *** SYSTEM PERIOD DATA ***
C**       J=1 THE LOAD DURATION CURVE NUMBER
 SYSP  (Y,P,J)    (2X,F6.4)
C
C-----------------------------------------------------------------------
C
C**       STAG  *** STATION GENERAL DATA ***
C**       L=1 TYPE OF STATION (USED BY GENERATION REDUCTION EQUATION)
C**            1-2 = NO GENERATION REDUCTION
C**            3-  =  GENERATION REDUCTION
C**            3   =  HYDRO
C**            4   =  PUMPED STORAGE
C**       L=2 PLANNED OR EXISTING STATION
C**            0= EXISTING
C**            1= PEAK PLANNED
C**            2= BASE PLANNED
C**            3= PLANNED PUMP STORAGE (NB FORGET TO UPDATE IPC IN STAP INFO)
C**       L=3 DFOR (DEFERRED FORCED OUTAGE RATE)
 STAG  (G,L)    (2X,F5.4)
C
C
C**       STAY  *** STATION YEAR DATA ***
C**       L=1 GENERATION ENERGY UPPER BOUND  (GEU) (GWH)
C**       L=2 GENERATION ENERGY LOWER BOUND  (GEL) (GWH)
C**       L=3 PLANNED OUTAGE  ATE (POR,Y)
 STAY  (G,Y,L)    (2X,F6.4)
C
C**       STAP  *** STATION PERIOD DATA ***
C**       V=1  GENERATION LOWER BOUND  (GOL)
C**       V=2  COST OF GENERATION   (KQO)
C**            ENTER SMALL DIFFERENCES IN COST FOR HYDRO,PUMP ST   )
C**            TO UTILISE FUNCTION VAR1()                          )
C**       V=3  INSTALLED GENERATION CAPACITY (IGC) (GW)
C**       V=4  PLANED OUTAGE RATE   (POR)
C**       V=5  FORCED OUTAGE RATE   (FOR)
C**       V=6  GENERATION ENERGY UPPER BOUND  (GEU)  (GWH)
C**       V=7  GENERATION ENERGY LOWER BOUND  (GEL)  (GWH)
C**       V=8  STATION EFFICIENCY (EFF)
C**       V=9  RESOURCE EFFICIENCY (REF)
C**       V=10 AUXILIARY COAL CONSUMPTION (AUX)
C**       V=11 AUXILIARY RESOURCE CONSUMPTION (RAX)
C**       V=12 PUMPING LOAD LOWER BOUND  (PLL)
C**       V=13 INSTALLED PUMPING CAPACITY (GW)
C**       V=14 PUMPSTORAGE INFLOW   (PSI) (GWH)
C**       V=15 INSTALLATION COST OF PLANNED STATION (GUP) (Rm)
 STAP  (G,Y,P,V)    (2X,F6.4)
C
C-----------------------------------------------------------------------
C
C**       PIMG  *** POWER IMPORT GENERAL DATA ***
C**       J=1
 PIMG  (I,J)    (2X,F6.4)
C
C
C**       PIMY  *** POWER IMPORT YEAR DATA ***
```

```
 W  NW        MAXW     52
C
C-----------------------------------------------------------------------
C            THE NUMBER OF YEARS IN THIS STUDY
 Y  NY        MAXY     10
C
C            THE NUMBER OF PERIODS IN THIS STUDY
 P  NP        MAXP     10
CP  NP        MAXP     52
C
C            THE NUMBER OF SLICES IN THIS STUDY
CS  NS        MAXS     10
 S  NS        MAXS     50
CS  NS        MAXS     100
C
C            THE NUMBER OF POWER STATIONS
CG  NG        MAXG     10
 G  NG        MAXG     22
CG  NG        MAXG     100
C
C            THE NUMBER OF COLLIERIES
 C  NC        MAXC     10
CC  NC        MAXC     50
C
C            THE NUMBER OF POWER IMPORT ROUTES
 I  NI        MAXI     10
CI  NI        MAXI     52
C
C            THE NUMBER OF POWER EXPORT ROUTES
 E  NE        MAXE     10
CE  NE        MAXE     52
C
C            THE NUMBER OF RESOURCES
CR  NR        MAXR     52
 R  NR        MAXR     10
C
C
C*********1*********2*********3*************************************
C
EXTERNAL VALUES
C
C
C
C**       LDC  *** LOAD DURATION CURVES ***
C**       L=1 THE NUMBER OF HOURS PER SLICE --(SWH,S)
C**       L=2 THE LOAD PER SLICE -- (PER UNIT OF WEEKLY MAX DEMAND)
C**       L=3 DFOR FACTOR
 LDC (P,S,L)      (2X,F6.4)
C
C
C**       WMC  *** WEEKLY MAXIMA CURVES ***
C**       K=1 THE PERIOD LENGTH IN WEEKS --(PLW,P)
C**       K=2 THE LOAD PER PERIOD -- (PER UNIT OF ANNUAL MAX DEMAND)
 WMC (W,P,K)      (2X,F6.4)
C
C-----------------------------------------------------------------------
C
C**       SYSG SYSTEM GENERAL DATA
 SYSG (K)         (2X,F8.2)
C
C
```

APPENDIX C

MGG SOURCE CODE

This appendix provides an example of the source code which serves as input to the Matrix Generator Generator and which is then converted FORTRAN code for the Matrix Generator.

```
C   FILE NAME source.mgg
C         THIS FILE HAS BEEN DESIGNED FOR TWO STUDIES
C         AND WAS CREATED ON 2 MAY 1990 - UPDATE 14/5/9.
C  THE SUBROUTINE SLICED IS USED TO GET THE DEMAND DATA
C********1*********2*********3************************************
C
NOTATION
C*******
C********1*********2*********3************************************
C
SUFFICES
C*******
C           DATA SUFFIX FROM 1 TO 1
 J  NJ        MAXJ     1
C
C           DATA SUFFIX FROM 1 TO 2
 K  NK        MAXK     2
C
C           DATA SUFFIX FROM 1 TO 3
 L  NL        MAXL     3
C
C           DATA SUFFIX FROM 1 TO 4
 M  NM        MAXM     4
C
C           DATA SUFFIX FROM 1 TO 5
 N  NN        MAXN     5
C
C           DATA SUFFIX FROM 1 TO 8
 T  NT        MAXT     8
C
C           DATA SUFFIX FROM 1 TO 9
 U  NU        MAXU     9
C
C           DATA SUFFIX FROM 1 TO 15
 V  NV        MAXV     15
C
C           DATA SUFFIX FROM 1 TO 52  (FOR WMC)
```

APPENDIX B

TYPE OF GENERATION EXPANSION STUDIES

- 50 year expansion plan
- 20 year expansion plan
- plant mix
- DSM
- marginal cost
    - tariff structure
    - design optimization
- interconnection
- foreign utilities
- plant design improvements
- availability improvements
- reliability
    - evaluation
    - optimal target
- plant refurbishment & decommissioning
- excess plant management
    - cancellation / delay options of plant under construction
    - reserve storage
    - mothballing / de-activating
- case studies
    - education
    - testing of new models
- long-term budget / production planning
- audit of other studies
- sensitivity analysis
- uncertainty analysis

RESOURCE CONSTRAINTS				
- PRODUCTION SCHEDULING				
RTB & $ y/p	pu	G/P	Resource Transfer Balance kRO-ōkGO = k	*

OBJECTIVE FUNCTION				
OBJ	Rm	G/P	OBJective function ōkGO+ōkPI-ōkPE+ōkGO+ōkGU+ ōkCO+ōkSL+ōkSI+ōkGO+ōkCI+ ōkTX+ōkTY+ōkTZ+ōkTI+ ōkRO+ōkRI	OB

RESOURCE VARIABLES

RO	&	y/p	pu	U(L)	G/P	Resource Output
RI	&	y/p	pu	BV	G	Resource Installation
RR	&	y/p	pu	BV	G	Resource Retirement

REFERENCE TABLE / CONSTRAINTS OF THE NEWGEX LP MODEL (PRODUCTION SCHEDULING)

NOTES (for abbreviations see App. A)

k	positive coefficient	*	variable not defined in old GEX
ð	summation (alt-228)	\	and/or
_	differentation (alt-235)	/	or

NAME	INDICES	UNIT	APP	DESCRIPTION EQUATION FOR	OLD GEX
GENERATION CONSTRAINTS					
- PRODUCTION SCHEDULING					
GLB	y p s	GW	G/P	Generation Load Balance ðGO+ðPI-ðPL-ðPE = k	ME
GEU $	y\p	GWh	G/P	Generation Energy Upper bound ðkGO <= k	H1
GEL $	y\p	GWh	G/P	Generation Energy Lower bound ðkGO >= k	H1
POB $	y	puh	G	Planned Outage Balance ðkPO = k	MA
PSB $	y p	GWh	G/P	Pumped Storage Balance ðkGO-ðkPL = k	P4
EIU i	y\p	GWh	G/P	Energy Import Upper bound ðkPI <= k	L1
EIL i	y\p	GWh	G/P	Energy Import Lower bound ðkPI >= k	L2
EEU e	y\p	GWh	G/P	Energy Export Upper bound ðkPE <= k	*
EEL e	y\p	GWh	G/P	Energy Export Lower bound ðkPE >= k	*
COAL CONSTRAINTS					
- PRODUCTION SCHEDULING					
GTB $	y/p	GWh	G/P	Generation Transfer Balance ðkGO-ðkTX-ðkTY-ðkTZ+ðkSI-ðkSO = -k	TR
CTB #	y/p	Mt	G/P	Coal Transfer Balance CO-ðTX-ðTY-ðTZ = 0	COP
SPB # $	y/p	Mt	P	StockPile Balance SI-SO-_SL = 0	*

APPENDIX A

REFERENCE TABLE / DECISION VARIABLES AND CONSTRAINTS

REFERENCE TABLE / DECISION VARIABLES OF THE NEWGEX LP MODEL

INDICES

$	power source	(power station ...)
#	coal source	(interconnected colliery, open-market ...)
&	other resource	(nuclear fuel, manpower, finance, environment ...)
i	import	(cogeneration ...)
e	export	(interconnection ...)
y	year	
p	period	
s	slice	

ABBREVIATIONS

BV	Bivalent Variable
U	Upper limit
L	Lower limit
G	Gen. exp. planning application
P	Production planning application

NOTES

*	variable not defined in old GEX
\	and/or
/	or
[]	optional

NAME	INDICES		UNIT	BNDS	APP	DESCRIPTION	OLD GEX
GENERATION VARIABLES							
GO	$	y p s	GW	U[L]	G/P	Generation Output	GE
PL	$	y p s	GW	U[L]	G/P	Pumping Load	PU
PI	i	y p s	GW	U[L]	G/P	Power Import	LN
PE	e	y p s	GW	U[L]	G/P	Power Export	*
PO	$	y p	pu		G	Planned Outage	MV
GC	$	y p	pu	BV	G	Generation Common equipment installation	BE
GU	$	y p	pu	BV	G	Generation Units installation	BS
GR	$	y p	pu	BV	G	Generation Retirement	*
COAL VARIABLES							
CO	#	y/p	Mt	U[L]	G/P	Colliery Output	CPD
TX	# $	y/p	Mt	[U[L]	G/P	Transport on channel X	U
TY	# $	y/p	Mt	[U[L]	G/P	Transport on channel Y	V
TZ	# $	y/p	Mt	[U[L]	G/P	Transport on channel Z	W
SL	# $	y/p	Mt	[U[L]	P	Stockpile Level at end of period or year	*
SI	# $	y/p	Mt	[U[L]	P	Stockpile Input	*
SO	# $	y/p	Mt	[U[L]	P	Stockpile Output	*
CI	#	y/p	pu	BV	G	Colliery Installation	CFC
CR	#	y/p	pu	BV	G	Colliery Retirement	*
TI	# $	y/p	pu	BV	G	Transport channel Installation	R
TR	# $	y/p	pu	BV	G	Transport channel Retirement	*

- Finally the importance of the statement "Garbage In-garbage Out (GIGO)" is particularly relevant in this type of model.

to enhance certain aspects of the programme improving the validity and value of the final product.

As part of the final product documentation was provided to facilitate the use of NewGex. This consisted of a simple step by step Production Planning - Operating Guide and was compiled by B van Schalkwyk, a fellow member of Information Technology - Integrated Connected Systems (Appendix G).

To conclude this document a number of important observations were made;

- It is important to make the input data as accurate as possible,

- It is necessary to have an adequate understanding of the formulae employed and how accurately they model reality is essential,

- It is realised that the final answer of a linear programming model has to be understood in relation to its sensitivity to changes which could occur,

```
      GE4 = STAP(G,Y,P,7)
C
C
C          *** YEAR
      GE5 = STAY(G,Y,2)
C
C*********1*********2*********3******************************************
C==========  SECTION 5.1.4
C     COEFFICIENTS FOR PLANNED OUTAGE BALANCE
C
      PO1 = PLW(Y,P,1)
C
      PO2 = STAY(G,Y,3) *  SUMPLW(Y)
C
C*********1*********2*********3******************************************
C==========  SECTION 5.1.5
C     COEFFICIENTS FOR PUMPED STORAGE BALANCE EQUATIONS
C
      PS1 = SWH(Y,P,S)
C                             EFF
      PS2 = SWH(Y,P,S) * STAP(G,Y,P,S)

C
C   AMOUNT OF WATER EXPRESSED IN GWH THAT FLOWED OUT
C                    PSO,P
      PS3 =  STAP(G,Y,P,14)
C
C*********1*********2*********3******************************************
C==========  SECTION 5.1.6
C     COEFFICIENTS FOR ENERGY IMPORT UPPER BOUND
C
C          *** PERIOD
      EI2 = PIMP(I,Y,P,4)
C
      EI1 = PLW(Y,P,1) * SWH(Y,P,S)
C
C
C          *** YEAR
      EI3 = PIMY(I,Y,1)
C
C*********1*********2*********3******************************************
C==========  SECTION 5.1.7
C     COEFFICIENTS FOR ENERGY IMPORT LOWER BOUND
C
C          *** PERIOD
      EI4 = PIMP(I,Y,P,5)
C
C          *** YEAR
      EI5 = PIMY(I,Y,2)
C
C*********1*********2*********3******************************************
C==========  SECTION 5.1.8
C     COEFFICIENTS FOR ENERGY EXPORT UPPER BOUND
C
C          *** PERIOD
      EE2 = PEXP(E,Y,P,4)
C
      EE1 = PLW(Y,P,1) * SWH(Y,P,S)
C
C
C          *** YEAR
```

```
C
C           STOCKPILE OUTPUT COST
C         *** PERIOD
      QSO= STPP(C,G,Y,P,9)
C         *** YEAR
      QOY= STPY(C,G,Y,9)
C
C---------------
C           COAL TRANSPORT COST ON CHANNEL "X"
C         *** PERIOD
      QTX= TCXP(C,G,Y,P,3)
C         *** YEAR
      QXY= TCXY(C,G,Y,3)
C
C           COAL TRANSPORT COST ON CHANNEL "Y"
C         *** PERIOD
      QTY= TCYP(C,G,Y,P,3)
C         *** YEAR
      QYY= TCYY(C,G,Y,3)
C
C           COAL TRANSPORT COST ON CHANNEL "Z"
C         *** PERIOD
      QTZ= TCZP(C,G,Y,P,3)
C         *** YEAR
      QZY= TCZY(C,G,Y,3)
C
C----------------------------------------------------------------------
C----------------   SECTION 6.3
C                   *** RESOURCE COSTS ***
C           RESOURCE VARIABLE OUTPUT COST
C         *** PERIOD
      QRO= RESP(R,Y,P,3)
C         *** YEAR
      QRY= RESY(R,Y,3)
C
C
C********1*********2*********3*****************************************
C----------  SECTION 5.1.1
C           MEGAWATT BALANCE EQUATION
C
      DMC = DMCS(Y,P,E)
C
C
C********1*********2*********3*****************************************
C----------  SECTION 5.1.2
C     COEFFICIENTS FOR GENERATION ENERGY UPPER BOUNDS
C
C         *** PERIOD
       GE2 = STAP(G,Y,P,6)
C
       GE1 = PLW(Y,P,1) * SWK(Y,P,8)
C
C
C         *** YEAR
       GE3 = STAY(G,Y,1)
C
C********1*********2*********3*****************************************
C----------  SECTION 5.1.3
C     COEFFICIENTS FOR GENERATION ENERGY LOWER BOUNDS
C
C         *** PERIOD
```

```
*    RTEY '***RRGGY'  NOT IF (RESSTN() .EQ. 0.)
        ROY(R,Y) - SUM(P,S) RT2 * GO(G,Y,P,S) .EQ. RT4
FOR ALL Y
FOR ALL G
FOR ALL R
CC
C************************************************************************
C
C*********1*********2*********3*************************************
C
ELEMENTS
C
C*********1*********2*********3*************************************
C
C          OBJECTIVE FUNCTION
C================   SECTION 6.1
C                *** COST OF GENERATING ***
C           VARIABLE O&M COSTS
      QGO=PLN(Y,P,1)*STAP(G,Y,P,2)*SWH(Y,P,S)*VAR1()
C
C           VARIABLE O&M COSTS FOR PUMPING OF PS STATIONS
      QPL=PLN(Y,P,1)*STAP(G,Y,P,15)*SWH(Y,P,S)*VAR1()
C
C
C           POWER IMPORT COST
      QPI= PLN(Y,P,1) * PIMP(G,Y,P,3) * SWH(Y,P,S)
C
C           POWER EXPORT REVENUE
      QPE= PLN(Y,P,1) * PEXP(G,Y,P,3) * SWH(Y,P,S)
C
C-----------------------------------------------------------------
C              PLANNED  STATION COST
      GUX= SYSG(1)
C-----------------------------------------------------------------
C              PLANNED  STATION COST
      GUY= SYSG(2)
C-----------------------------------------------------------------
C      PLANNED PEAK STATION AVAILABILITY COEFFICIENT
      GOP= (1-STAP(G,Y,P,4))*(1-STAP(G,Y,P,5))*
     *       (1-LDC(1,S,3)*STAG(G,3))
C
C================   SECTION 6.2
C                *** COAL COSTS ***
C          COLLIERY VARIABLE OUTPUT COST
C         *** PERIOD
      QCO= COLP(C,Y,P,3)
C         *** YEAR
      QCY= COLY(C,Y,3)
C
C--------------
C           STOCKPILE LEVEL COST
C         *** PERIOD
      QSL= STPP(C,G,Y,P,3)
C         *** YEAR
      QLY= STPY(C,G,Y,3)
C
C           STOCKPILE INPUT COST
C         *** PERIOD
      QSI= STPP(C,G,Y,P,6)
C         *** YEAR
```

```
C          FOR EACH SELECTED STOCKPILE
C          FOR EACH PERIOD IN EACH YEAR
C
C    ***** THE FIRST PERIOD OF THE STUDY *****
*    USTB1 '*CCGGYPP'  NOT IF ((STBFL() .EQ. 0.).OR.(STPG(C,G,1).LE. 0.))
       T(C,G,Y,P) - O(C,G,Y,P) - S(C,G,Y,P) .EQ. - SLI
FOR P = 1
FOR Y = 1
FOR ALL G
FOR ALL C
C
C                    ********************
C
*    STB '*CCGGYPP'  NOT IF (P.EQ.1 .OR.(STBFL().EQ. 0.))
       T(C,G,Y,P) - O(C,G,Y,P) + S(C,G,Y,P1) - S(C,G,Y,P) .EQ. 0.0
FOR P1 = P - 1
FOR ALL P
FOR ALL Y
FOR ALL G
FOR ALL C
C
C          ************************************
C          STOCKPILE BALANCE
C          FOR EACH SELECTED STOCKPILE
C          FOR EACH YEAR
C
C    ***** THE FIRST YEAR OF THE STUDY *****
*    YSTB1 '***CCGGY'  NOT IF ((STBYFL() .EQ. 0.).OR.(STPG(C,G,1).LE. 0.))

       SI(C,G,Y) - SO(C,G,Y) - SL(C,G,Y) .EQ. - SLI
FOR Y = 1
FOR ALL G
FOR ALL C
C
C                    ********************
C
*    STBY '***CCGGY'  NOT IF (Y .EQ. 1.OR.(STBYFL().EQ. 0.))
       SI(C,G,Y) - SO(C,G,Y) + SL(C,G,Y1) - SL(C,G,Y) .EQ. 0.0
FOR Y1 = Y - 1
FOR ALL Y
FOR ALL G
FOR ALL C
C
C************************************************************************
C*********  SECTION 5.3.1
C          RESOURCE TRANSFER BALANCE
C          FOR EACH SELECTED RESOURCE
C          FOR EACH PERIOD IN EACH YEAR
C
*    RTB '*RRGGYPP'  NOT IF (RESSTN() .EQ. 0.)
       RO(R,Y,P) - SUM(S) RT2 * GO(G,Y,P,S) .EQ. RT3
FOR ALL P
FOR ALL Y
FOR ALL G
FOR ALL R
C
C                    ********************
C          RESOURCE TRANSFER BALANCE
C          FOR EACH SELECTED RESOURCE
C          FOR EACH YEAR
C
```

```
C          GENERATION TRANSFER BALANCE CONSTRAINT FOR THE PERIOD
C          FOR EACH SELECTED POWER STATION
C          FOR EACH PERIOD IN EACH YEAR
C
*     GTB '***GGYPP' NOT IF(STAP(G,Y,P,13).GT. 0. .OR.(GTBFL().EQ. 0.))
           SUM(S) GT1 * GO(G,Y,P,S)
       -   SUM(C) CVL * X(C,G,Y,P)
       -   SUM(C) CVL * Y(C,G,Y,P)
       -   SUM(C) CVL * Z(C,G,Y,P)
       +    SUM(C) CVL * T(C,G,Y,P)
       -    SUM(C) GT2 * O(C,G,Y,P)  .EQ. GT3
FOR ALL P
FOR ALL Y
FOR ALL G
C
C          ****************************************************
C          GENERATION TRANSFER BALANCE CONSTRAINT FOR THE PERIOD
C          FOR EACH SELECTED POWER STATION
C          FOR  EACH YEAR
C
*     GTBY '**** GGY' NOT IF((STAP(G,Y,1,13).GT. 0.) .OR. (GTBYFL().EQ.0.))
           SUM(P,S) GT1 * GO(G,Y,P,S)
       -   SUM(C) CVY * TX(C,G,Y)
       -   SUM(C) CVY * TY(C,G,Y)
       -   SUM(C) CVY * TZ(C,G,Y)
       +    SUM(C) CVY * SI(C,G,Y)
       -    SUM(C) GT4 * SO(C,G,Y)  .EQ. GT5
FOR ALL Y
FOR ALL G
C FOR ALL C
C
C
C*************************************************************************
C********* SECTION 5.2.2
C          COAL TRANSFER BALANCE
C          FOR EACH COLLIERY
C          FOR EACH PERIOD IN EACH YEAR
C
*     CTB '***CCYPP' NOT IF (COLP(C,Y,P,4) .EQ. 0.)
        CO(C,Y,P) - SUM (G) X(C,G,Y,P)
        - SUM (G) Y(C,G,Y,P) - SUM (G) Z(C,G,Y,P)  .EQ.  0.0
FOR ALL P
FOR ALL Y
FOR ALL C
C
C
C          ***********************************
C          COAL TRANSFER BALANCE
C          FOR EACH COLLIERY
C          FOR EACH YEAR
C
*     CTBY '****CCY' NOT IF (COLY(C,Y,4) .EQ. 0.)
        COY(C,Y) - SUM (G) TX(C,G,Y)
        - SUM (G) TY(C,G,Y) - SUM (G) TZ(C,G,Y)  .EQ.  0.0
FOR ALL Y
FOR ALL C
C
C
C*************************************************************************
C********* SECTION 5.2.3
C          STOCKPILE BALANCE
```

```
                SUM (S) EI1 * IPI(I,Y,P,S) .GE. EI4
FOR ALL P
FOR ALL Y
FOR ALL I
C
C             ************************************
C       ENERGY IMPORT LOWER BOUND - CONSTRAINTS FOR
C       SELECTED POWER IMPORT SOURCES IN EACH SELECT YEAR
C
*  EILY '**** IIY' NOT IF (PIMY(I,Y,2) .EQ. 0.0)
C
               SUM (P,S) EI1 * IPI(I,Y,P,S) .GE. EI5
FOR ALL Y
FOR ALL I
C
C**************************************************************************
C*********  SECTION 5.1.8
C       ENERGY EXPORT UPPER BOUND - CONSTRAINTS FOR
C       SELECTED POWER IMPORT SOURCES IN EACH SELECT PERIOD
C
*  EEU '***EEYPP' NOT IF (PEXP(E,Y,P,4) .EQ. 0.0)
C
               SUM (S) EE1 * EPE(E,Y,P,S) .LE. EE2
FOR ALL P
FOR ALL Y
FOR ALL E
C
C             ************************************
C       ENERGY EXPORT UPPER BOUND - CONSTRAINTS FOR
C       SELECTED POWER IMPORT SOURCES IN EACH SELECTED YEAR
C
*  EEUY '**** EEY' NOT IF (PEXY(E,Y,1) .EQ. 0.0)
C
               SUM (P,S) EE1 * EPE(E,Y,P,S) .LE. EE3
FOR ALL Y
FOR ALL E
C
C**************************************************************************
C*********  SECTION 5.1.9
C       ENERGY EXPORT LOWER BOUND - CONSTRAINTS FOR
C       SELECTED POWER IMPORT SOURCES IN EACH SELECTED PERIOD
C
*  EEL '***EEYPP' NOT IF (PEXP(E,Y,P,5) .EQ. 0.0)
C
               SUM (S) EE1 * EPE(E,Y,P,S) .GE. EE4
FOR ALL P
FOR ALL Y
FOR ALL E
C
C             ************************************
C       ENERGY EXPORT LOWER BOUND - CONSTRAINTS FOR
C       SELECTED POWER IMPORT SOURCES IN EACH SELECTED YEAR
C
*  EELY '**** EEY' NOT IF (PEXY(E,Y,2) .EQ. 0.0)
C
               SUM (P,S) EE1 * EPE(E,Y,P,S) .GE. EE5
FOR ALL Y
FOR ALL E
C
C**************************************************************************
```

```
C      GENERATION ENERGY LOWER BOUND FOR FOR ADDITIONAL
C      CONSTRAINTS ON STATIONS FOR THE YEAR
C
*   GELY '**** GGY' NOT IF (STAY(G,Y,2) .EQ. 0.0)
C
              SUM (P,S) GE1 * GO(G,Y,P,S) .GE. GE5
FOR ALL Y
FOR ALL G
C
C
C*****************************************************************************
C**********  SECTION 5.1.4
C      PLANNED OUTAGE BALANCE -  CONSTRAINTS ON SELECTED
C      POWER STATIONS IN EACH SELECTED YEAR
C
*   POB '*** GGY' NOT IF  (STAY(G,Y,3) .EQ. 0)
C
              SUM (P) PO1 * PO(G,Y,P) .EQ. PO2
FOR ALL Y
FOR ALL G
C
C*****************************************************************************
C**********  SECTION 5.1.5
C           THE PUMP STORAGE BALANCE EQUATION
C
*   PSB '***GGYPP'    NOT IF (STAP(G,Y,P,13).EQ. 0.)
C
        SUM(S) PS1 * GO(G,Y,P,S) - SUM(S) PS2 * LPL(G,Y,P,S) .EQ. PS3
FOR  ALL P
FOR  ALL Y
FOR  ALL G
C
C*****************************************************************************
C**********  SECTION 5.1.6
C      ENERGY IMPORT UPPER BOUND - CONSTRAINTS FOR
C      SELECTED POWER IMPORT SOURCES IN EACH SELECTED PERIOD
C
*   EIU '***IIYPP' NOT IF (PIMP(I,Y,P,4) .EQ. 0.0)
C
              SUM (S) EI1 * IPI(I,Y,P,S) .LE. EI2
FOR ALL P
FOR ALL Y
FOR ALL I
C
C              ********************************
C      ENERGY IMPORT UPPER BOUND - CONSTRAINTS FOR
C      SELECTED POWER IMPORT SOURC"S IN EACH SELECTED YEAR
C
*   EIUY '**** IIY' NOT IF (PIMY(I,Y,1) .EQ. 0.0)
C
              SUM (P,S) EI1 * IPI(I,Y,P,S) .LE. EI3
FOR ALL Y
FOR ALL I
C
C*****************************************************************************
C**********  SECTION 5.1.7
C      ENERGY IMPORT LOWER BOUND - CONSTRAINTS FOR
C      SELECTED POWER IMPORT SOURCES IN EACH SELECTED PERIOD
C
*   EIL '***IIYPP' NOT IF (PIMP(I,Y,P,5) .EQ. 0.0)
```

```
C              UPPER BOUND EQUATION OF PLANNED BASE LOAD STATIONS
*   BBN     '*GGYPPSS'   NOT IF (STAG(G,2) .NE. 2.)
         GO(G,Y,P,S) - GOP*DBN .LE. 0.0
FOR ALL S
FOR ALL P
FOR ALL Y
FOR ALL G
C
C
C*****************************************************************************
C              UPPER BOUND OF PUMPING FOR PLANNED PUMPED STORAGE STATIONS
*   QPN    '*GGYPPSS'   NOT IF (STAG(G,2) .NE. 3.)
         LPL(G,Y,P,S) - GOP*DPN .LE. 0.0
FOR ALL S
FOR ALL P
FOR ALL Y
FOR ALL G
C
C*****************************************************************************
C              PUMPING INCREASE CONSTRAINT
*   VPIC  '*GGYPPSS' NOT IF (STAG(G,1) .NE. 4.0)
         LPL(G,Y,P,S1) - LPL(G,Y,P,S) .GE. 0.0
FOR S1 = S + 1
C S NE NS INCLUDED TO ENSURE NO INFEASIBILITY DUE TO DWA
FOR S.NE.NS
FOR ALL P,Y,G
C
C*********  SECTION 5.1.2
C     GENERATION ENERGY UPPER BOUND FOR ADDITIONAL
C     CONSTRAINTS ON STATIONS DURING SELECTED PERIODS
C
*  GEU '***GGYPP' NOT IF (STAP(G,Y,P,6) .EQ. 0.0)
C
            SUM (S) GE1 * GO(G,Y,P,S) .LE. GE2
FOR ALL P
FOR ALL Y
FOR ALL G
C
C       ******************************
C     GENERATION ENERGY UPPER BOUND FOR FOR ADDITIONAL
C     CONSTRAINTS ON STATIONS FOR THE YEAR
C
*  GEUY '**** GGY' NOT IF (STAY(G,Y,1) .EQ. 0.0)
C
            SUM (P,S) GE1 * GO(G,Y,P,S) .LE. GE3
FOR ALL Y
FOR ALL G
C
C*****************************************************************************
C*********  SECTION 5.1.3
C     GENERATION ENERGY LOWER BOUND FOR ADDITIONAL
C     CONSTRAINTS ON STATIONS DURING SELECTED PERIODS
C
*  GEL '***GGYPP' NOT IF (STAP(G,Y,P,7) .EQ. 0.0)
C
            SUM (S) GE1 * GO(G,Y,P,S) .GE. GE4
FOR ALL P
FOR ALL Y
FOR ALL G
C
C       ******************************
```

```
        SUM(G,Y,P,S) QGO * GO(G,Y,P,S)
   -    SUM(G,Y,P,S) QPL * LPL(G,Y,P,S)
   +    SUM(I,Y,P,S) QPI * IPI(I,Y,P,S)
   -    SUM(E,Y,P,S) QPE * EPE(E,Y,P,S)
   +    SUM(C,Y,P)   QCO * CO(C,Y,P)
   +    SUM(C,Y)     QCY * COY(C,Y)
   +    SUM(C,G,Y,P) QSL * S(C,G,Y,P)
   +    SUM(C,G,Y)   QLY * SL(C,G,Y)
   +    SUM(C,G,Y,P) QSI * T(C,G,Y,P)
   +    SUM(C,G,Y)   QIY * SI(C,G,Y)
   +    SUM(C,G,Y,P) QSO * O(C,G,Y,P)
   +    SUM(C,G,Y)   QOY * SO(C,G,Y)
   +    SUM(C,G,Y,P) QTX * X(C,G,Y,P)
   +    SUM(C,G,Y)   QXY * TX(C,G,Y)
   +    SUM(C,G,Y,P) QTY * Y(C,G,Y,P)
   +    SUM(C,G,Y)   QYY * TY(C,G,Y)
   +    SUM(C,G,Y,P) QTZ * Z(C,G,Y,P)
   +    SUM(C,G,Y)   QZY * TZ(C,G,Y)
   +    SUM(R,Y,P)   QRO * RO(R,Y,P)
   +    SUM(R,Y)     QRY * ROY(R,Y)
   +                 GUX * DPN
   +                 GUY * DBN
C
C*************************************************************************
C*************************************************************************
C*************************************************************************
SUBJECT TO
C
C*************************************************************************
C***************     SECTION 5.1.1
C                GENERATION LOAD BALANCE
*   GL    '**YPPSS'   NOT IF (SWH(Y,P,S)  .LE. 0)
       SUM (G) GO(G,Y,P,S)
     + SUM (I) IPI(I,Y,P,S)
     - SUM (G) LPL(G,Y,P,S)
     - SUM (E) EPE(E,Y,P,S) .EQ. DMC
FOR ALL S
FOR ALL P
FOR ALL Y
C
C
C*************************************************************************
C                GENERATION REDUCTION CONSTRAINT
*   WGRC  '*GGYPPSS' NOT IF (STAG(G,1) .LT. 2.S)
        GO(G,Y,P,S1) - GO(G,Y,P,S) .LE. 0.0
FOR S1 = S + 1
FOR S.NE.NS
C SEE VPIC FOR REASON WHY S NE NS (INCLUDED HERE ONLY TO BE CONSISTENT
C WITH VPIC CONSTRAINT
FOR ALL P,Y,G
C*************************************************************************
C                UPPER BOUND EQUATION OF PLANNED PEAK LOAD STATIONS
*    APN   '*GGYPPSS' NOT IF ((STAG(G,2) .NE.1.).AND.(STAG(G,2).NE.3.))
        GO(G,Y,P,S) - GOP*DPN .LE. 0.0
FOR ALL S
FOR ALL P
FOR ALL Y
FOR ALL G
C
C
C*************************************************************************
```

```
 S  (C,G,Y,P)  '*CCGGYPP'  NOT IF (STPP(C,G,Y,P,1).EQ. 0.)
BOUND UP SLU NOT IF (STPP(C,G,Y,P,1).EQ. 0.)
BOUND LO SLL NOT IF (STPP(C,G,Y,P,2).EQ. 0.)
C
C        SL   *** STOCKPILE LEVEL "SL" AT END OF YEARS (MEGA TONS)
C
 SL  (C,G,Y)   '**CCGGY'   NOT IF (STPY(C,G,Y,1).EQ. 0.)
BOUND UP YLU NOT IF (STPY(C,G,Y,1).EQ. 0.)
BOUND LO YLL NOT IF (STPY(C,G,Y,2).EQ. 0.)
C                                    ************
C
C        T    *** STOCKPILE INPUT "SI" AT END OF PERIODS (MEGA TONS)
C
 T  (C,G,Y,P)  '*CCGGYPP'  NOT IF (STPP(C,G,Y,P,4).EQ. 0.)
BOUND UP SIU NOT IF (STPP(C,G,Y,P,4).EQ. 0.)
BOUND LO SIL NOT IF (STPP(C,G,Y,P,5).EQ. 0.)
C
C        SI   *** STOCKPILE INPUT "SI" AT END OF YEARS (MEGA TONS)
C
 SI  (C,G,Y)   '**CCGGY'  NOT IF (STPY(C,G,Y,4).EQ. 0.)
BOUND UP YIU NOT IF (STPY(C,G,Y,4).EQ. 0.)
BOUND LO YIL NOT IF (STPY(C,G,Y,5).EQ. 0.)
C                                    ************
C
C        O    *** STOCKPILE OUTPUT "SO" AT END OF PERIODS (MEGA TONS)
C
 O  (C,G,Y,P)  '*CCGGYPP'  NOT IF (STPP(C,G,Y,P,7).EQ. 0.)
BOUND UP SOU NOT IF (STPP(C,G,Y,P,7).EQ. 0.)
BOUND LO SOL NOT IF (STPP(C,G,Y,P,8).EQ. 0.)
C
C        SO   *** STOCKPILE OUTPUT "SO" AT END OF YEARS (MEGA TONS)
C
 SO  (C,G,Y)   '**CCGGY'  NOT IF (STPY(C,G,Y,7).EQ. 0.)
BOUND UP YOU NOT IF (STPY(C,G,Y,7).EQ. 0.)
BOUND LO YOL NOT IF (STPY(C,G,Y,8).EQ. 0.)
C                                    ************
C
C        RO   *** RESOURCE OUTPUT "RO" FOR PERIOD (PU)
C
 RO  (R,Y,P)   '** RRYPP'  NOT IF (RESP(R,Y,P,1).EQ. 0.)
BOUND UP ROU NOT IF (RESP(R,Y,P,1).EQ. 0.)
BOUND LO ROL NOT IF (RESP(R,Y,P,2).EQ. 0.)
C
C        ROY  *** RESOURCE OUTPUT "SRO FOR,THE YEARS (PU)
C
 ROY (R,Y)   '*** RRY'  NOT IF (RESY(R,Y,1).EQ. 0.)
BOUND UP RYU NOT IF (RESY(R,Y,1).EQ. 0.)
BOUND LO RYL NOT IF (RESY(R,Y,2).EQ. 0.)
C
C
C
C********1*********2*********3****************************************
C
PROBLEM
C********1*********2*********3****************************************
C********1*********2*********3****************************************
C********1*********2*********3****************************************
C
MINIMIZE
C                                       ## OBJECTIVE FUNCTION ##
* PCOST   '******'
```

```
C
C         PO  *** PLANNED OUTAGE (PU) ***
 PO (G,Y,P)  '** GGYPP' NOT IF(STAY(G,Y,3).EQ. 0.)
C
C                                        ************
C
C         COY  *** COLLIERY OUTPUT IN A YEAR (MEGA TONS)
C
 COY  (C,Y)   '*** CCY'  NOT IF (COLY(C,Y,4).EQ. 0.)
BOUND UP CYU
BOUND LO CYL NOT IF (COLY(C,Y,2).EQ. 0.)
C                                        ************
C
C         CO  *** COLLIERY OUTPUT IN A PERIOD(MEGA TONS)
C
 CO  (C,Y,P)   '** CCYPP'  NOT IF (COLP(C,Y,P,4).EQ. 0.)
BOUND UP COU
BOUND LO COL NOT IF (COLP(C,Y,P,2).EQ. 0.)
C                                        ************
C
C         X   *** COAL TRANSPORTED ON CHANNEL  TX IN PERIODS (MEGA TONS)
C
 X  (C,G,Y,P)   '*CCGGYPP'  NOT IF (TCXP(C,G,Y,P,1).EQ. 0.)
BOUND UP TXU NOT IF (TCXP(C,G,Y,P,1).EQ. 0.)
BOUND LO TXL NOT IF (TCXP(C,G,Y,P,2).EQ. 0.)
C
C         TX   *** COAL TRANSPORTED ON CHANNEL  TX IN YEARS (MEGA TONS)
C
 TX  (C,G,Y)   '**CCGGY'  NOT IF (TCXY(C,G,Y,1).EQ. 0.)
BOUND UP YXU NOT IF (TCXY(C,G,Y,1).EQ. 0.)
BOUND LO YXL NOT IF (TCXY(C,G,Y,2).EQ. 0.)
C                                        ************
C
C         Y   *** COAL TRANSPORTED ON CHANNEL  TY IN PERIODS (MEGA TONS)
C
 Y  (C,G,Y,P)   '*CCGGYPP'  NOT IF (TCYP(C,G,Y,P,1).EQ. 0.)
BOUND UP TYU NOT IF (TCYP(C,G,Y,P,1).EQ. 0.)
BOUND LO TYL NOT IF (TCYP(C,G,Y,P,2).EQ. 0.)
C
C         TY   *** COAL TRANSPORTED ON CHANNEL  TY IN YEARS (MEGA TONS)
C
 TY  (C,G,Y)   '**CCGGY'  NOT IF (TCYY(C,G,Y,1).EQ. 0.)
BOUND UP YYU NOT IF (TCYY(C,G,Y,1).EQ. 0.)
BOUND LO YYL NOT IF (TCYY(C,G,Y,2).EQ. 0.)
C                                        ************
C
C         Z   *** COAL TRANSPORTED ON CHANNEL  TZ IN PERIODS (MEGA TONS)
C
 Z  (C,G,Y,P)   '*CCGGYPP'  NOT IF (TCZP(C,G,Y,P,1).EQ. 0.)
BOUND UP TZU NOT IF (TCZP(C,G,Y,P,1).EQ. 0.)
BOUND LO TZL NOT IF (TCZP(C,G,Y,P,2).EQ. 0.)
C
C         TZ   *** COAL TRANSPORTED ON CHANNEL  TZ IN YEARS (MEGA TONS)
C
 TZ  (C,G,Y)   '**CCGGY'  NOT IF (TCZY(C,G,Y,1).EQ. 0.)
BOUND UP YZU NOT IF (TCZY(C,G,Y,1).EQ. 0.)
BOUND LO YZL NOT IF (TCZY(C,G,Y,2).EQ. 0.)
C                                        ************
C
C         S   *** STOCKPILE LEVEL "SL" AT END OF PERIODS (MEGA TONS)
C
```

```
C       SUMRT4    *** COEFFICINT "4" OF RESOURCE   ***
C                 *** TRANSFER BALANCE CONSTRAINT ***
 SUMPLW   (Y)
 SUMGT5   (G,Y)
 SUMRT4   (G,Y)
C
        CALL sliced
C
C*********1*********2*********3****************************************
C
DECLARATIONS
C
C
C
C*********1*********2*********3****************************************
C
VARIABLES
C
C
C
C          GO  *** GENERATION OUTPUT FOR A SPECIFIC SLICE (GW) ***
 GO (G,Y,P,S)    '*GGYPPSS' NOT IF (SWH(Y,P,S) .EQ. 0.0)
C
BOUND UP GOU NOT IF ((STAG(G,2) .EQ. 1.).OR.(STAG(G,2) .EQ. 2.))
BOUND LO GOL NOT IF (STAP(G,Y,P,1).EQ. 0.)
C                                          ============
C
C          DPN  *** UPPER BOUND GENERATION OF PLANNED PEAK LOAD STATION
 DPN              '****'
C
C
C                                          ============
C
C          DBN  *** UPPER BOUND GENERATION OF PLANNED BASE LOAD STATION
 DBN              '****'
C
C                                          ============
C
C          LPL  *** PUMP LOAD FOR A SPECIFIC SLICE (GW) ***
C
 LPL (G,Y,P,S) '*GGYPPSS' NOT IF
((STAP(G,Y,P,13).EQ.0.).OR.(SWH(Y,P,S).EQ.0.))
BOUND UP PLU NOT IF ((STAP(G,Y,P,13).EQ. 0.).OR.(SWH(Y,P,S).EQ. 0.))
BOUND LO PLL NOT IF ((STAP(G,Y,P,12).EQ. 0.).OR.(SWH(Y,P,S).EQ. 0.))
C                                          ============
C
C          IPI  *** POWER IMPORT FOR A SPECIFIC SLICE (GW) ***
 IPI (I,Y,P,S) '*IIYPPSS' NOT IF((SWH(Y,P,S).EQ. 0.).OR.(PIMP(I,Y,P,1).EQ.
0.))
BOUND UP PIU
BOUND LO PIL NOT IF (PIMP(I,Y,P,2).EQ. 0.)
C
C                                          ============
C
C          EPE  *** POWER EXPORT FOR A SPECIFIC SLICE (GW) ***
 EPE (E,Y,P,S) '*EEYPPSS' NOT IF((SWH(Y,P,S).EQ. 0.).OR.(PEXP(E,Y,P,1).EQ.
0.))
BOUND UP PEU
BOUND LO PEL NOT IF (PEXP(E,Y,P,2).EQ. 0.)
C
C                                          ============
```

```
SYSP        1990        03              1
*
*   STAG   *** STATION GENERAL DATA ***
*          J=1 TYPE OF STATION
*
*        STATION          TYPE
*        --------        ------
STAG        UNEN              1
STAG        PEAK              2
STAG        MDMT              3
STAG        BASE              4
*
*   STAY   *** STATION YEAR DATA ***
*          L=1 GENERATION ENERGY UPPER BOUND   (GEU)  (GWH)
*          L=2 GENERATION ENERGY LOWER BOUND   (GEL)  (GWH)
*          L=3 PLANNED OUTAGE RATE (AVERAGE)  (POR,Y)
*
*        STATION      YEAR             GEU     GEL     POR
*        --------  --------          ------  ------  ------
STAY        UNEN      1990          8736.0  0000.0  0000.2
STAY        BASE      1990          0000.0  25000.  0000.1
*
*   STAP   *** STATION PERIOD DATA ***
*          V=1  GENERATION LOWER BOUND   (GOL)  (GW)
*          V=2  COST OF GENERATION   (QGO)
*          V=3  INSTALLED GENERATION CAPACITY  (IGC)  (GW)
*          V=4  PLANED OUTAGE RATE   (POR)
*          V=5  FORCED OUTAGE RATE   (FOR)
*          V=6  GENERATION ENERGY UPPER BOUND   (GEU)  (GWH)
*          V=7  GENERATION ENERGY LOWER BOUND   (GEL)  (GWH)
*          V=8  STATION EFFICIENCY (EFF)
*          V=9  RESOURCE EFFICIENCY (REF)
*          V=10 AUXILIARY COAL CONSUMPTION (AUX)
*          V=11 AUXILIARY RESOURCE CONSUMPTION (RAX)
*          V=12 PUMPING LOAD LOWER BOUND   (PLL)
*          V=13 INSTALLED PUMPING CAPACITY   (IPC)  (GW)
*          V=14 PUMPSTORAGE INFLOW  (PSI)  (GWH)
*
*        STATION      YEAR  PERIODS  SEQ     GOL     QGO     IGC     POR     FOR
*        --------  -------- -------- ----  ------  ------  ------  ------  ------
STAP        UNEN      1990       01    1  0000.0  0000.0  002.00  0.2000  0.0500
STAP        UNEN      1990       02    1  0000.0  0000.0  002.00  0.1000  0.0500
STAP        UNEN      1990       03    1  0000.0  0000.0  002.00  0.2000  0.0500
STAP        PEAK      1990       01    1  0000.0  0010.0  001.80  0.0000  0.0200
STAP        PEAK      1990       02    1  0000.0  0010.0  001.80  0.0000  0.0200
STAP        PEAK      1990       03    1  0000.0  0010.0  001.80  0.0000  0.0200
STAP        MDMT      1990       01    1  0000.0  0008.0  001.80  0.0000  0.0300
STAP        MDMT      1990       02    1  0000.0  0008.0  001.80  0.0000  0.0300
STAP        MDMT      1990       03    1  0000.0  0008.0  001.80  0.0000  0.0300
STAP        BASE      1990       01    1  0000.0  0004.0  003.90  0.1000  0.0450
STAP        BASE      1990       02    1  0000.0  0004.0  003.90  0.0000  0.0450
STAP        BASE      1990       03    1  0000.0  0004.0  003.90  0.1000  0.0450
*
*        STATION      YEAR  PERIODS  SEQ     GEU     GEL     EFF     REF     AUX
*        --------  -------- -------- ----  ------  ------  ------  ------  ------
STAP        UNEN      1990       01    2  0000.0  0000.0  1.0000  0001.0  0000.0
```

```
KINAME  002          SNAW
*
* EXP ROUTE          SUFFIX
*       -----        --------
KENAME  001          SWAW
KENAME  002          MAPU
*
* RESOURCE           SUFFIX
*       -----        --------
KRNAME  001          H2O1
KRNAME  002          MENP
*
*  LDC  *** LOAD DURATION CURVES ***
*       K=1 THE NUMBER OF HOURS PER SLICE --(SWH,8)
*       K=2 THE LOAD PER SLICE -- (PER UNIT OF WEEKLY MAX DEMAND)
*
*       CURVE NO  SLICES         SWH     LOAD
*       --------  --------      ------  ------
LDC          01       001       015.00  1.0000
LDC          01       002       020.00  0.9000
LDC          01       003       080.00  0.8000
LDC          01       004       033.00  0.7000
LDC          01       005       015.00  0.6500
LDC          01       006       005.00  0.6000
*
*
*  WMC  *** WEEKLY MAXIMA CURVES ***
*       K=1 THE PERIOD LENGTH IN WEEKS --(PLW,9)
*       K=2 THE LOAD PER PERIOD -- (PER UNIT OF ANNUAL MAX DEMAND)
*
*       CURVE NO  PERIODS        PLW     LOAD
*       --------  --------      ------  ------
WMC           1        01       17.000  0.7500
WMC           1        02       18.000  0.8500
WMC           1        03       17.000  0.8000
*
*  SYSG *** SYSTEM GENERAL DATA ***
*             ------
SYSG          00.000
*
*
*  SYSY  *** SYSTEM YEAR DATA ***
*        K=1 THE LOAD PEAK FOR THE YEAR  (GW)
*        K=2 THE WEEKLY MAXIMA CURVE NUMBER
*
*           YEAR         LOAD     WMC
*       --------       ------  ------
SYSY        1990       07.000       1
*
*  SYSP  *** SYSTEM PERIOD DATA ***
*        J=1 THE LOAD DURATION CURVE NUMBER
*
*           YEAR  PERIODS             LDC
*       --------  --------         ------
SYSP        1990       01               1
SYSP        1990       02               1
```

```
*
*  MGPROD.D
*  MG FILE TO TEST MGG FORMULATION FILE
*  FOR NEWGEX PRODUCTION SYSTEM
*  10/04/90
*
TITLE     NEWGEX TEST
*
*         NUMBER--NAME
*
VERSION  1        TEST
*
MAXIMA    NY = 6 NP = 4 NS = 5 NG = 5 NC = 4 NI = 2 NE = 2 NR = 2
*
EXTERNAL VALUES
*
*       YEAR       SUFFIX
*       -----      --------
KYNAME   01            1990
*
*      PERIOD      SUFFIX
*       -----      --------
KPNAME   01              01
KPNAME   02              02
KPNAME   03              03
*
*       SLICE      SUFFIX
*       -----      --------
KSNAME   01             001
KSNAME   02             002
KSNAME   03             003
KSNAME   04             004
KSNAME   05             005
KSNAME   06             006
*
*     STATION      SUFFIX
*       -----      --------
KGNAME  001            UNEN
KGNAME  002            PEAK
KGNAME  003            MDMT
KGNAME  004            BASE
*
*  COLLIERY        SUFFIX
*       -----      --------
KCNAME  001            TCOA
KCNAME  002            OPTI
KCNAME  003            DUVA
*
* IMP ROUTE        SUFFIX
*       -----      --------
KINAME  001            CAHB
```

APPENDIX D

MGG DATA INPUT

A typical data input file is illustrated in theis section. It is such a template which was setup for the user of the system to create his own studies.

```
     +              'DMCS(',I1,':',I1,':',I1,')',F8.2)
C
                 ELSE
                   GOTO 110
                 END IF
 100          CONTINUE
C                PERIOD LENGTH WEEKS
 110             PLW(IY,IP) = WMC(NWMC,IP,1)
             WRITE(6,188)IY,IP,PLW(IY,IP)
             WRITE(3,188)IY,IP,PLW(IY,IP)
 188        FORMAT (1X,'*** PLW(',I1,':',I1,F8.2)
             CONTINUE
            CONTINUE
C
C **********
C
        RETURN
        END
```

```
C*****************************************************************************
C       FUNCTION DMCS()
C
C      THIS FUNCTION CALCULATES THE CONSUMER DEMAND PER SLICE
C **********
C
C       NWDC = SYSY(Y,2)
C       NLDC = SYSP(Y,P,1)
C        IF(LDC(NLDC,S,1) .EQ. 0.0) DMCS = 0.0
C          DMCS = LDC(NLDC,S,2) * WMC(NWMC,P,2) * SYSY(Y,1)
C       RETURN
C      END
C
C*****************************************************************************
C**************
C
C*********1*********2*********3************************************
ENDATA
```

SUBROUTINE SLICED

```
      SUBROUTINE SLICED
C
C        : THIS SUBROUTINE DETERMINES THE DEMANDS FOR
C        : EACH SLICE, SLICE WIDTHS AND  PERIOD LENGTHS
C
C
      INCLUDE (MGCOMS)
C
C
C  **********
C        CALCULATE DEMAND IN SLICE AND SLICE WIDTH
           DO 140 IY = 1,NY
C            NUMBER OF WEEKLY MAX CURVE
             NWMC = SYSY(IY,2)
             DO 110 IP = 1,NP
                IF(WMC(NWMC,IP,1) .GT. 0.0) THEN
                  GOTO 90
                ELSE
                  GOTO 140
                END IF
C              NUMBER OF WEEKLY MAX CURVE
90             NLDC = SYSP(IY,IP,1)
               DO 100 IS = 1,NS
C
C                 WIDTH OF SLICE
                  IF(LDC(NLDC,IS,1) .GT. 0.0) THEN
                    SWH(IY,IP,IS) = LDC(NLDC,IS,1)
C                   DEMAND OF CONSUMER
                    DMCS(IY,IP,IS) = LDC(NLDC,IS,2) * WMC(NWMC,IP,2)
     +                             * SYSY(IY,1)
      WRITE(6,198)IY,IP,IS,SWH(IY,IP,IS),IY,IP,IS,DMCS(IY,IP,IS)
      WRITE(3,198)IY,IP,IS,SWH(IY,IP,IS),IY,IP,IS,DMCS(IY,IP,IS)
 198  FORMAT (1X,'SWH(',I1,':',I1,':',I1,')',F8.2,
```

```
C
C         SUMGT5 = 0
C          DO 100  IP = 1,NP
C            IF (PLW(Y,P,1) .EQ. 0.) GOTO 110
C 100        SUMGT5 = SUMGT5 +  PLW(Y,P,1) * STAP(G,Y,P,10) *
                      STAP(G,Y,P,3) * PLW(Y,P,2)
C 110   RETURN
C       END
C
C****************************************************************************
C       FUNCTION SUMRT4()
C
C    THIS FUNCTION SUMS THE TERMS FOR COEFFICIENT "RT4"
C **********
C
C         SUMRT4 = 0
C          DO 100  IP = 1,NP
C            IF (PLW(Y,IP,1) .EQ. 0.) GOTO 110
C 100        SUMRT4 = SUMRT4 + PLW(Y,IP,1) * STAP(G,Y,IP,11) *
                      STAP(G,Y,IP,3) * PLW(Y,P,2)
C 110   RETURN
C       END
C
C****************************************************************************
C       FUNCTION SUMSLICE()
C
C            THIS FUNCTION SUMS THE "SWH'S" FOR A PERIOD
C **********
C
C         SUMSLICE = 0
C         IY = Y
C         IP = P
C          DO 100  IS = 1,NS
C            IF (SWH(IY,IP,IS) .EQ. 0.) GOTO 110
C            SUMSLICE = SUMSLICE + PLW(IY,IP,IS)
C 100   CONTINUE
C 110   RETURN
C       END
C
C****************************************************************************
C            THIS FUNCTION CALCULATES THE WIDTH OF A SLICE
C **********
C*********  SECTION 5.1.3
C       NLDC = SYSP(Y,P,1)
C        IF(LDC(NLDC,S,1) .EQ. 0.0) SWH = 0.0
C           SWH = LDC(NLDC,S,1)
C       RETURN
C       END
C
C****************************************************************************
C       FUNCTION PLW()
C
C            THIS FUNCTION CALCULATES THE PERIOD LENGTH
C **********
C
C       NWDC = SYSY(Y,2)
C        IF(WMC(NWMC,P,1) .EQ. 0.0) PLW = 0.0
C           PLW = WMC(NWMC,P,1)
C       RETURN
C       END
C
```

```
      WRITE(RESO(1:4),'(A4)') RESG(R,1)
      WRITE(STNM(1:4),'(A4)') KGNAME(G)
        IF (RESO(1:4) .EQ. STNM(1:4)) RESSTN = 1.0
     RETURN
     END
C***************
C*******************************************************************************
      FUNCTION    GTBFL()
C
C     FLAG FOR THE GTB CONSTRAINT
C
      GTBFL  =  0.0
C
      DO 20 II = 1,NC
      GTBFL = GTBFD + COLP(II,Y,P,4)
  20  CONTINUE
      RETURN
      END
C***************
C*******************************************************************************
      FUNCTION    GTBYFL()
C
C     FLAG FOR THE GTBY CONSTRAIN
C
      GTBYFL  =  0.0
C
      DO 20 II = 1,NC
      GTBYFL = GTBYFL + COLY(II,Y,4)
  20  CONTINUE
      RETURN
      END
C***************
C*******************************************************************************
      FUNCTION    STBFL()
C
C     FLAG FOR THE STB CONSTRAINT
C
      STBFL  =  0.0
      IF((STPP(C,G,Y,P,4).GT. 0.).AND.(STPP(C,G,Y,P,7).GT. 0.)) THEN
        STBFL = 1.0
      ENDIF
      RETURN
      END
C***************
C*******************************************************************************
      FUNCTION    STBYFL()
C
C     FLAG FOR THE STBY CONSTRAINT
C
      STBYFL  =  0.0
      IF((STPY(C,G,Y,4).GT. 0.).AND.(STPY(C,G,Y,7).GT. 0.)) THEN
       STBYFL = 1.0
      ENDIF
      RETURN
      END
C***************
C*******************************************************************************
C     FUNCTION SUMGT5()
C
C   THIS FUNCTION SUMS THE TERMS FOR COEFFICIENT "GT5"
C *********
```

```
C       BOUNDS  SET FOR VARIABLE "O"   (SO,P)
C UPPER =>
         SOU    = STPP(C,G,Y,P,7)
C LOWER =BOUND
         SOL    = STPP(C,G,Y,P,8)
C
C-----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "SO"
C UPPER =>
         YOU    = STPY(C,G,Y,7)
C LOWER =BOUND
         YOL    = STPY(C,G,Y,8)
C
C-----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "RO"
C UPPER =>
         ROU    = RESP(R,Y,P,1)
C LOWER =BOUND
         ROL    = RESP(R,Y,P,2)
C
C-----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "ROY"
C UPPER =>
         RYU    = RESY(R,Y,1)
C LOWER =BOUND
         RYL    = RESY(R,Y,2)
C
C-----------------------------------------------------------------
C
C****************************************************************
FUNCTIONS
C================================================================
      FUNCTION VAR1()
C     CHECKS WHETHER HYDRO OR PUMPED STATION AND MULTIPLIES
C     THE COST QGO WITH A FACTOR TO AVOID THOSE STATIONS
C     TO BE SWITCHED DURING OPTIMISATION
        IF ((STAG(G,1).EQ.3.).OR.(STAG(G,1).EQ.4.)) THEN
          VAR1 = 1.0 + (LDC(1,S,3)/10000.0)
        ELSE
          VAR1 = 1.0
        ENDIF
        RETURN
      END
C================================================================
C      FUNCTION VAR2()
C      VAR2 = 0.0
C         IF (STAG(G,1) .EQ. 4.) THEN
C         VAR2 = 1.0 + (LDC(1,S,3)/10000.0)
C         ENDIF
C         RETURN
C      END
C================================================================
      FUNCTION RESSTN()
C           THIS FUNCTION DETERMINES IF A RESOURCE
C           AND STATION CORRESPOND
C =========
        CHARACTER  RESO * 4
        CHARACTER  STNM * 4
C
C
      RESSTN = 0.0
```

```
C        BOUNDS  SET FOR VARIABLE "TX"
C UPPER =>
          YXU    = TCXY(C,G,Y,1)
C LOWER =BOUND
          YXL    = TCXY(C,G,Y,2)
C-----------------------------------------------------------------
C        BOUNDS  SET FOR VARIABLE "Y"
C UPPER =>
          TYU = TCYP(C,G,Y,P,1)
C LOWER =>
          TYL = TCYP(C,G,Y,P,2)
C
C-----------------------------------------------------------------
C        BOUNDS  SET FOR VARIABLE "TY"
C UPPER =>
          YYU    = TCZY(C,G,Y,1)
C LOWER =BOUND
          YYL    = TCZY(C,G,Y,2)
C-----------------------------------------------------------------
C        BOUNDS  SET FOR VARIABLE "Z"
C UPPER =>
          TZU = TCZP(C,G,Y,P,1)
C LOWER =>
          TZL = TCZP(C,G,Y,P,2)
C
C-----------------------------------------------------------------
C        BOUNDS  SET FOR VARIABLE "TZ"
C UPPER =>
          YZU    = TCZY(C,G,Y,1)
C LOWER =BOUND
          YZL    = TCZY(C,G,Y,2)
C
C-----------------------------------------------
C        BOUNDS  SET FOR VARIABLE "S"
C UPPER =>
          SLU    = STPP(C,G,Y,P,1)
C LOWER =BOUND
          SLL    = STPP(C,G,Y,P,2)
C
C-----------------------------------------------------------------
C        BOUNDS  SET FOR VARIABLE "SL"
C UPPER =>
          YLU    = STPY(C,G,Y,1)
C LOWER =BOUND
          YLL    = STPY(C,G,Y,2)
C
C-----------------------------------------------------------------
C        BOUNDS  SET FOR VARIABLE "T"  (SI,P)
C UPPER =>
          SIU    = STPP(C,G,Y,P,4)
C LOWER =BOUND
          SIL    = STPP(C,G,Y,P,5)
C
C-----------------------------------------------------------------
C        BOUNDS  SET FOR VARIABLE "SI"
C UPPER =>
          YIU    = STPY(C,G,Y,4)
C LOWER =BOUND
          YIL    = STPY(C,G,Y,5)
C
C-----------------------------------------------------------------
```

```
      GOU = STAP(G,Y,P,3)*(1-STAP(G,Y,P,4))*(1-STAP(G,Y,P,5))*
     *       (1-LDC(1,S,3)*STAG(G,3))
C
C LOWER =>
        GOL = STAP(G,Y,P,1)
C
C----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "PL"
C      ADF IS NOT DEFINED FOR THIS MODEL IE. ADF = 1
C
C UPPER =>GOU = IPC * (1-POR) * (I-FOR) * ADF ?
      PLU = STAP(G,Y,P,13)*(1-STAP(G,Y,P,4))*(1-STAP(G,Y,P,5))*
     *       (1-LDC(1,S,3)*STAG(G,3))
C
C LOWER =>
        PLL = STAP(G,Y,P,12)
C
C----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "PI"
C
C UPPER =>
        PIU = PIMP(I,Y,P,1)
C
C LOWER =>
        PIL = PIMP(I,Y,P,2)
C
C----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "PE"
C
C UPPER =>
        PEU = PEXP(E,Y,P,1)
C
C LOWER =>
        PEL = PEXP(E,Y,P,2)
C
C----------------------------------------------------------------
C**********  SECTION 3.21
C       BOUNDS  SET FOR VARIABLE "COY"
C
C UPPER =>
        CYU = COLY(C,Y,1)
C
C LOWER =>
        CYL = COLY(C,Y,2)
C
C----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "CO"
C UPPER=>
        COU = COLP(C,Y,P,1)
C
C LOWER=>
        COL = COLP(C,Y,P,2)
C
C----------------------------------------------------------------
C       BOUNDS  SET FOR VARIABLE "X"
C UPPER =>
        TXU = TCXP(C,G,Y,P,1)
C LOWER =>
        TXL = TCXP(C,G,Y,P,2)
C
C----------------------------------------------------------------
```

```
      EE3 = PEXY(E,Y,1)
C
C*********1*********2*********3************************************
C========== SECTION 5.1.9
C    COEFFICIENTS FOR ENERGY IMPORT LOWER BOUND
C
C        *** PERIOD
      EE4 = PEXP(E,Y,P,5)
C
C        *** YEAR
      EE5 = PEXY(E,Y,2)
C
C*********1*********2*********3************************************
C========== SECTION 5.2.1
C    COEFFICIENTS FOR GENERATION TRANSFER BALANCE

C
C        *** PERIOD
      GT1 =    SWH(Y,P,8) * PLW(Y,P,1) / STAP(G,Y,P,8)
C
      GT2 =    COLP(C,Y,P,5) * COLP(C,Y,P,4) / 3.6
C
      GT3 = -1 *PLW(Y,P,1) *STAP(G,Y,P,10) *STAP(G,Y,P,3) *PLW(Y,P,2)
C
      CVL =    COLP(C,Y,P,4) / 3.6
C
C        *** YEAR
      GT4 =    COLY(C,Y,5) * COLY(C,Y,4) / 3.6
C
      GT5 =    -1 * SUMGT5(G,Y)
C
      CVY =    COLY(C,Y,4) / 3.6
C
C*********1*********2*********3************************************
C========== SECTION 5.2.3
C    COEFFICIENTS FOR STOCKPILE BALANCE
C
      SLI =    STPG(C,G,1)
C
C
C*********1*********2*********3************************************
C========== SECTION 5.3.1
C    COEFFICIENTS FOR RESOURCE TRANSFER BALANCE
C
C        *** PERIOD
      RT2 =    SWH(Y,P,8) * PLW(Y,P,1) / STAP(G,Y,P,9)
C
      RT3 =    PLW(Y,P,1) * STAP(G,Y,P,11) * STAP(G,Y,P,3) * PLW(Y,P,2)
C
C        *** YEAR
      RT4 =    SUMRT4(G,Y)
C
C
C*********1*********2*********3************************************
C*********1*********2*********3*******
C========== SECTION 3.1
C       BOUNDS  SET FOR VARIABLE "GO"
C
C UPPER =>GOU = IGC * (1-POR) * (1-FOR) * ADF ?
C       ADF IS NOT DEFINED FOR THIS MODEL IE. ADF = 1
C
```

```
      IF (TOPRGO(IJ).GT.0.000001) THEN
C        WRITE OUT INFORMATION FOR EACH STATION
      WRITE (KPRINT,2140) KGNAME(IJ),(PRGO(K),K=NUMPRD,NPRD)
      WRITE (KPRINT,2145)
      END IF
         DO 2130 K = NUMPRD,NPRD
         PRGO(K) = 0.0
2130     CONTINUE
2140  FORMAT (1X,'# ',A,T13,'#',10(1X,F8.2))
2145  FORMAT ('+',T100)
C
      IF ((NPRD .EQ. NP).AND. (TOPRGO(IJ).GT.0.000001)) THEN
       WRITE(KPRINT,2150) TOPRGO(IJ)
2150  FORMAT ('+',T110,'#',1X,F10.2,T100)
      ENDIF
2100  CONTINUE
        NUMPRD = NUMPRD + 10
2090  CONTINUE
C
2000  CONTINUE
C
C
C ==================COLLIERIES===================================
C
C
C        ===***=== START PRINTING THE TABLE ===***===
C                   INITIALISING VARIABLES
      NPRD    = 0
      NUMPRD  = 0
      NUYR    = 0
      TYPE    = 0
C
C
      DO 3080 III = 1,200
       TOPRGO(III) = 0.0
3080  CONTINUE
C
        NUMPRD = 1
C
      DO 3100 II = 1,NY,10
       IF ((NPRD+10) .GE. NY) THEN
         NPRD = NY
       ELSE
         NPRD =NPRD +10
       ENDIF
C
C ====***=== WRITING TABLE HEADINGS ===***===
C
```

```
C
C
C ==================PUMPING LOAD==============================
C
C       ===***=== START PRINTING THE TABLE ===***===
C                INITIALISING VARIABLES
      NPRD   = 0
      NUMPRD = 0
      NUYR   = 0
      TYPE   = 0
C
C
      DO 2090 II = 1,NY
C
      DO 2080 III = 1,200
       TOPRGO(III) = 0.0
2080  CONTINUE
C
        NUMPRD = 1
C
      DO 2090 IK = 1,NP,10
       IF ((NPRD+10) .GE. NP) THEN
         NPRD = NP
       ELSE
         NPRD =NPRD +10
       ENDIF
C
      DO 2100 IJ = 1,NG
C
C ====***=== WRITING TABLE HEADINGS ===***===
C
       IF (IJ .EQ. 1) THEN
C           *TYPE* SPECIFIES WHICH TABLE IS BEING PRINTED
              TYPE = 2
           CALL TBHEAD (TYPE,NUMPRD,NPRD,II)
       ENDIF
C
C          ONLY TO BE DONE FOR PUMPED STORAGE STATIONS
C ????????             IF (POWR1(IJ,2) .NE. 1.0)GOTO 2100
C
      DO 2110 I = NUMPRD,NPRD
C
      DO 2120 J = 1,NS
C
      PRGO(I) = PRGO(I) + BLPL(IJ,II,I,J)*SWH(II,I,J)*PLW(II,I,1)
2120  CONTINUE
      TOPRGO(IJ) = PRGO(I) + TOPRGO(IJ)
2110  CONTINUE
```

```
C
       NUMPRD = 1
C
      DO 1090 IK = 1,NP,10
       IF ((NPRD+10) .GE. NP) THEN
         NPRD = NP
       ELSE
         NPRD =NPRD +10
       ENDIF
C
      DO 1100 IJ = 1,NG
C
C ====***=== WRITING TABLE HEADINGS ===***===
C
       IF (IJ .EQ. 1) THEN
C           'TYPE' SPECIFIES WHICH TABLE IS BEING PRINTED
              TYPE = 1
            CALL TBHEAD (TYPE,NUMPRD,NPRD,II)
       ENDIF
C
1115  DO 1110 I = NUMPRD,NPRD
C
      DO 1120 J = 1,NS
C
C
      PRGO(I) = PRGO(I) + BGO(IJ,II,I,J)*SWH(II,I,J)*PLW(II,I,1)
1120  CONTINUE
      TOPRGO(IJ) = PRGO(I) + TOPRGO(IJ)
1110  CONTINUE
C        WRITE OUT INFORMATION FOR EACH STATION
      WRITE (KPRINT,1140) KGNAME(IJ),(PRGO(K),K=NUMPRD,NPRD)
      WRITE (KPRINT,1145)
         DO 1130 K = NUMPRD,NPRD
         PRGO(K) = 0.0
1130     CONTINUE
1140  FORMAT (1X,'# ',A,T13,'#',10(1X,F8.2))
1145  FORMAT ('+',T100)
C
      IF (NPRD .EQ. NP) THEN
       WRITE(KPRINT,1150) TOPRGO(IJ)
1150  FORMAT ('+',T110,'#',1X,F10.2,T100)
      ENDIF
1100  CONTINUE
       NUMPRD = NUMPRD + 10
1090  CONTINUE
C
1000  CONTINUE
C
```

```
      SUBROUTINE REPORT
C     ========== ======
C*****************************************************
C*****************************************************
C*****  THIS REPORTWRITER WAS CREATED FOR THE    *****
C*****     NEWGEX PROJECT 4 FEBUARY 1990         *****
C*****            BY  L. R. BOTHA                *****
C*****  AND MODIFIED BY P. DE WINTER 24/4/90     *****
C*****************************************************
C*****************************************************
C..  - used parameters to dimension local arrays
C..
C
%INCLUDE 'MGCOMS.I'
                                          NOTE
%INCLUDE 'RWCOMM.I'
C
      CHARACTER *10  RANGEV (100,2,4)
      CHARACTER *8   RANGEX (168,6)
      CHARACTER *1   AII
      CHARACTER *2   AIJ
      CHARACTER *2   AK
C
      REAL RANGER(100,2)
      REAL RANGEY(100,2)
C
      REAL PRGO(200),TOPRGO(200)
      REAL SUM
C
      INTEGER NUMPRD,NPRD,TYPE
C
C
C       ===***=== START PRINTING THE TABLE ===***===
C                 INITIALISING VARIABLES
      NPRD   = 0
      NUMPRD = 0
      NWHEAD = 0
      TYPE   = 0
C
C      CALL RANGS1
C
      DO 1000 II = 1,NY
C
      DO 1080 III = 1,200
       TOPRGO(III) = 0.0
1080  CONTINUE
```

APPENDIX E

REPORT WRITER CODE

The Report Writer code is shown in this appendix. Note the inclusion of the common blocks produced by RUNMGG and Sciconic namely 'MGCOMS.I' and 'RWCMM.I'.

```
*
*        RRRR              ----
*RESG    H201              BASE
*
*  RESY   *** RESOUCE YEAR DATA ***
*          L=1  RESOUCE OUTPUT UPPER BOUND   (ROU)
*          L=2  RESOUCE OUTPUT LOWER BOUND   (ROL)
*          L=3  RESOUCE OUTPUT COST   (KRO)
*
*          RRRR       YYYY          -ROU--  -ROL--  -QRO--
*RESY     H201        1990          900000  000010  .02000
*
*  RESP   *** RESOUCE PERIOD DATA ***
*          L=1  RESOUCE OUTPUT UPPER BOUND   (ROU)
*          L=2  RESOUCE OUTPUT LOWER BOUND   (ROL)
*          L=3  RESOUCE OUTPUT COST   (KRO)
*
*          RRRR       YYYY    PP               -ROU--  -ROL--  -QRO--
*RESP      H201        1990    01               900000  000000  .02000
*RESP      H201        1990    02               900000  000000  .02000
*RESP      H201        1990    03               900000  000000  .02000
*
ENDATA
```

```
*STPP    TCOA    PEAK    1991    03    1    000100  000010  .00100  000100
*STPP    DUVA    MDMT    1990    01    1    000100  000005  .00200  000100
*STPP    DUVA    MDMT    1990    02    1    000100  000005  .00200  000100
*STPP    DUVA    MDMT    1990    03    1    000100  000005  .00200  000100
*STPP    DUVA    MDMT    1991    01    1    000100  000005  .00200  000100
*STPP    DUVA    MDMT    1991    02    1    000100  000005  .00200  000100
*STPP    DUVA    MDMT    1991    03    1    000100  000005  .00200  000100
*STPP    OPTI    BASE    1990    01    1    000200  000008  .00300  000100
*STPP    OPTI    BASE    1990    02    1    000200  000008  .00300  000100
*STPP    OPTI    BASE    1990    03    1    000200  000008  .00300  000100
*STPP    OPTI    BASE    1991    01    1    000200  000008  .00300  000100
*STPP    OPTI    BASE    1991    02    1    000200  000008  .00300  000100
*STPP    OPTI    BASE    1991    03    1    000200  000008  .00300  000100
*
*        CCCC    GGGG    YYYY    PP    SEQ  -SIL--  -QSI--  -SOU--  -SOL--
*STPP    TCOA    PEAK    1990    01    2    .00000  .00100  010000  000000
*STPP    TCOA    PEAK    1990    02    2    .00000  .00100  010000  000000
*STPP    TCOA    PEAK    1990    03    2    .00000  .00100  010000  000000
*STPP    TCOA    PEAK    1991    01    2    .00000  .00100  010000  000000
*STPP    TCOA    PEAK    1991    02    2    .00000  .00100  010000  000000
*STPP    TCOA    PEAK    1991    03    2    .00000  .00100  [illegible]  000000
*STPP    DUVA    MDMT    1990    01    2    .00000  .00200  [illegible]  000000
*STPP    DUVA    MDMT    1990    02    2    .00000  .00200  010100  000000
*STPP    DUVA    MDMT    1990    03    2    .00000  .00200  010100  000000
*STPP    DUVA    MDMT    1991    01    2    .00000  .00200  010100  000000
*STPP    DUVA    MDMT    1991    02    2    .00000  .00200  010100  000000
*STPP    DUVA    MDMT    1991    03    2    .00000  .00200  010100  000000
*STPP    OPTI    BASE    1990    01    2    .00000  .00100  011100  000000
*STPP    OPTI    BASE    1990    02    2    .00000  .00100  011100  000000
*STPP    OPTI    BASE    1990    03    2    .00000  .00100  011100  000000
*STPP    OPTI    BASE    1991    01    2    .00000  .00100  011100  000000
*STPP    OPTI    BASE    1991    02    2    .00000  .00100  011100  000000
*STPP    OPTI    BASE    1991    03    2    .00000  .00100  011100  000000
*
*        CCCC    GGGG    YYYY    PP    SEQ  -QSO--
*STPP    TCOA    PEAK    1990    01    3    .00100
*STPP    TCOA    PEAK    1990    02    3    .00100
*STPP    TCOA    PEAK    1990    03    3    .00100
*STPP    TCOA    PEAK    1991    01    3    .00100
*STPP    TCOA    PEAK    1991    02    3    .00100
*STPP    TCOA    PEAK    1991    03    3    .00100
*STPP    DUVA    MDMT    1990    01    3    .00200
*STPP    DUVA    MDMT    1990    02    3    .00200
*STPP    DUVA    MDMT    1990    03    3    .00200
*STPP    DUVA    MDMT    1991    01    3    .00200
*STPP    DUVA    MDMT    1991    02    3    .00200
*STPP    DUVA    MDMT    1991    03    3    .00200
*STPP    OPTI    BASE    1990    01    3    .00100
*STPP    OPTI    BASE    1990    02    3    .00100
*STPP    OPTI    BASE    1990    03    3    .00100
*STPP    OPTI    BASE    1991    01    3    .00100
*STPP    OPTI    BASE    1991    02    3    .00100
*STPP    OPTI    BASE    1991    03    3    .00100
*
*  RESG  *** RESOUCE GENERA  DATA ***
*        J=1
```

```
*        L=3  TRANSPORT COST ON CHANNEL (QTZ)
*
*        CCCC       GGGG      YYYY      PP                  -TXU--  -TXL--  -QTX--
*TGZP    OPTI       BASE      1990      01                  000050  000000  0.0050
*
*
*  STPG  *** STOCKPILE GENERAL DATA ***
*        J=1  INITIAL STOCKPILE LEVEL   (SLI)
*
*       CCCC        GGGG          -SLI--
*STPG   OPTI        BASE          00010.
*
*  STPY  *** STOCKPILE YEAR DATA ***
*        U=1  STOCKPILE LEVEL UPPER BOUND   (SLU)
*        U=2  STOCKPILE LEVEL LOWER BOUND   (SLL)
*        U=3  STOCKPILE LEVEL COST   (QSL)
*        U=4  STOCKPILE INPUT UPPER BOUND   (SIU)
*        U=5  STOCKPILE INPUT LOWER BOUND   (SIL)
*        U=6  STOCKPILE INPUT COST   (QSI)
*        U=7  STOCKPILE OUTPUT UPPER BOUND   (SOU)
*        U=8  STOCKPILE OUTPUT LOWER BOUND   (SOL)
*        U=9  STOCKPILE OUTPUT COST   (QSO)
*
*        CCCC       GGGG      YYYY    SEQ    -SLU--  -SLL--  -QSL--  -SIU--  -SIL--
*STPY    TCOA       PEAK      1990    1      000900  000030  .00300  000600  000000
*STPY    TCOA       PEAK      1991    1      000900  000030  .00300  000600  000000
*STPY    DUVA       MDMT      1990    1      000900  000020  .00400  000500  000000
*STPY    DUVA       MDMT      1991    1      000900  000020  .00400  000500  000000
*STPY    OPTI       BASE      1990    1      000900  000020  .00200  000500  000000
*STPY    [illegible] BASE     1991    1      000900  000020  .00200  000500  000000
*
*        [illegible] GGGG     YYYY    SEQ    -QSI--  -SOU--  -SOL--  -QSO--
*STPY    TCOA       PEAK      1990    2      .00100  000500  000000  .00100
*STPY    TCOA       PEAK      1991    2      .00100  000500  000000  .00100
*STPY    DUVA       MDMT      1990    2      .00100  000500  000000  .00200
*STPY    DUVA       MDMT      1991    2      .00100  000500  000000  .00200
*STPY    OPTI       BASE      1990    2      .00100  000400  000000  .00200
*STPY    OPTI       BASE      1991    2      .00100  000400  000000  .00200
*
*  STPP  *** STOCKPILE PERIOD DATA ***
*        U=1  STOCKPILE LEVEL UPPER BOUND (SLU)
*        U=2  STOCKPILE LEVEL LOWER BOUND(SLL)
*        U=3  STOCKPILE LEVEL COST (KSL)
*        U=4  STOCKPILE INPUT UPPER BOUND (SIU)
*        U=5  STOCKPILE INPUT LOWER BOUND(SIL)
*        U=6  STOCKPILE INPUT COST (KSI)
*        U=7  STOCKPILE OUTPUT UPPER BOUND (SOU)
*        U=8  STOCKPILE OUTPUT LOWER BOUND(SOL)
*        U=9  STOCKPILE OUTPUT COST (KSO)
*
*        CCCC       GGGG      YYYY    PP          SEQ    -SLU--  -SLL--  -QSL--  -SIU--
*STPP    TCOA       PEAK      1990    01          1      000100  000010  .00100  000100
*STPP    TCOA       PEAK      1990    02          1      000100  000010  .00100  000100
*STPP    TCOA       PEAK      1990    03          1      000100  000010  .00100  000100
*STPP    TCOA       PEAK      1991    01          1      000100  000010  .00100  000100
*STPP    TCOA       PEAK      1991    02          1      000100  000010  .00100  000100
```

```
*TCXP    TCOA      PEAK     1990     03                010000  000000  0.0100
*TCXP    TCOA      PEAK     1991     01                010000  000000  0.0100
*TCXP    TCOA      PEAK     1991     02                010000  000000  0.0100
*TCXP    TCOA      PEAK     1991     03                010000  000000  0.0100
*TCXP    DUVA      MDMT     1990     01                010000  000000  0.0200
*TCXP    DUVA      MDMT     1990     02                010000  000000  0.0200
*TCXP    DUVA      MDMT     1990     03                010000  000000  0.0200
*TCXP    DUVA      MDMT     1991     01                010000  000000  0.0200
*TCXP    DUVA      MDMT     1991     02                010000  000000  0.0200
*TCXP    DUVA      MDMT     1991     03                010000  000000  0.0200
*TCXP    OPTI      BASE     1990     01                010000  000000  0.0070
*TCXP    OPTI      BASE     1990     02                010000  000000  0.0070
*TCXP    OPTI      BASE     1990     03                010000  000000  0.0070
*TCXP    OPTI      BASE     1991     01                010000  000000  0.0070
*TCXP    OPTI      BASE     1991     02                010000  000000  0.0070
*TCXP    OPTI      BASE     1991     03                010000  000000  0.0070
*
*  TCYG  *** TRANSPORT ON CHANNEL 'Y' GENERAL DATA ***
*        J=1
*
*      CCCC          ------
*TCYG  TCOA
*
*  TCYY  *** TRANSPORT ON CHANNEL 'Y' YEAR DATA ***
*        L=1  TRANSPORT CHANNEL 'Y' UPPER BOUND (TYU)
*        L=2  TRANSPORT CHANNEL 'Y' LOWER BOUND(TYL)
*        L=3  TRANSPORT COST ON CHANNEL (QTY)
*
*        CCCC      GGGG      YYYY          -TXU--  -TYL--  -QTY--
*TCYY    TCOA      PEAK      1990          000010  000000  .00900
*
*  TCYP  *** TRANSPORT ON CHANNEL 'Y' PERIOD DATA ***
*        L=1  TRANSPORT CHANNEL 'Y' UPPER BOUND (TYU)
*        L=2  TRANSPORT CHANNEL 'Y' LOWER BOUND (TYL)
*        L=3  TRANSPORT COST ON CHANNEL (QTY)
*
*        CCCC      GGGG      YYYY     PP              -TYU--  -TYL--  -QTY--
*TCYP    OPTI      BASE      1990     01              000010  000000  0.0060
*
*  TCZG  *** TRANSPORT ON CHANNEL 'Z' GENERAL DATA ***
*        J=1
*
*      CCCC          ------
*TCZG  TCOA
*
*  TCXY  *** TRANSPORT ON CHANNEL 'Z' YEAR DATA ***
*        L=1  TRANSPORT CHANNEL 'Z' UPPER BOUND (TZU)
*        L=2  TRANSPORT CHANNEL 'Z' LOWER BOUND(TZL)
*        L=3  TRANSPORT COST ON CHANNEL (QTZ)
*
*        CCCC      GGGG      YYYY          -TZU--  -TZL--  -QTZ--
*TCZY    TCOA      PEAK      1990          000010  000000  .00800
*
*  TCZP  *** TRANSPORT ON CHANNEL 'Z' PERIOD DATA ***
*        L=1  TRANSPORT CHANNEL 'Z' UPPER BOUND (TZU)
*        L=2  TRANSPORT CHANNEL 'Z' LOWER BOUND (TZL)
```

```
*COLY    DUVA      1991         900000  000000  0.5000  0.1800  1.0000
*
*  COLP   *** COLLIERY PERIOD DATA ***
*         N=1  COLLIERY OUTPUT UPPER BOUND (COU)  (MT)
*         N=2  COLLIERY OUTPUT LOWER BOUND (COL)  (MT)
*         N=3  COLLIERY OUTPUT COST (QCO)   (RM/MT)
*         N=4  CALORIFIC VALUE  (CVL)   (TJ/MT)
*         N=5        CVR
*
*        CCCC      YYYY      PP           -COU--  -COL--  -QCO--  -CVL--  -CVR--
*COLP     TCOA      1990      01           100000  000000  0.2000  0036.0  1.0000
*COLP     TCOA      1990      02           100000  000000  0.2000  0036.0  1.0000
*COLP     TCOA      1990      03           100000  000000  0.2000  0036.0  1.0000
*COLP     TCOA      1991      01           100000  000000  0.2000  0036.0  1.0000
*COLP     TCOA      1991      02           100000  000000  0.2000  0036.0  1.0000
*COLP     TCOA      1991      03           100000  000000  0.2000  0036.0  1.0000
*COLP     OPTI      1990      01           100000  000000  0.3000  0072.0  1.0000
*COLP     OPTI      1990      02           100000  000000  0.3000  0072.0  1.0000
*COLP     OPTI      1990      03           100000  000000  0.3000  0072.0  1.0000
*COLP     OPTI      1991      01           100000  000000  0.3000  0072.0  1.0000
*COLP     OPTI      1991      02           100000  000000  0.3000  0072.0  1.0000
*COLP     OPTI      1991      03           100000  000000  0.3000  0072.0  1.0000
*COLP     DUVA      1990      01           100000  000000  0.5000  1008.0  1.0000
*COLP     DUVA      1990      02           100000  000000  0.5000  1008.0  1.0000
*COLP     DUVA      1990      03           100000  000000  0.5000  1008.0  1.0000
*COLP     DUVA      1991      01           100000  000000  0.5000  1008.0  1.0000
*COLP     DUVA      1991      02           100000  000000  0.5000  1008.0  1.0000
*COLP     DUVA      1991      03           100000  000500  0.5000  0018.0  1.0000
*
*  TCXG   *** TRANSPORT ON CHANNEL 'X' GENERAL DATA ***
*         J=1
*
*       CCCC            ------
*TCXG   TCOA
*
*  TCXY   *** TRANSPORT ON CHANNEL 'X' YEAR DATA ***
*         L=1  TRANSPORT CHANNEL 'X' UPPER BOUND (TXU)
*         L=2  TRANSPORT CHANNEL 'X' LOWER BOUND(TXL)
*         L=3  TRANSPORT COST ON CHANNEL (QTX)
*
*        CCCC      GGGG      YYYY         -TXU--  -TXL--  -QTX--
*TCXY    TCOA      PEAK      1990         900000  000000  .01000
*TCXY    TCOA      PEAK      1991         900000  000000  .01000
*TCXY    DUVA      MDMT      1990         900000  000000  .02000
*TCXY    DUVA      MDMT      1991         900000  000000  .02000
*TCXY    OPTI      BASE      1990         900000  000000  .02000
*TCXY    OPTI      BASE      1991         900000  000000  .02000
*
*  TCYY   *** TRANSPORT ON CHANNEL 'X' PERIOD DATA ***
*         L=1  TRANSPORT CHANNEL 'X' UPPER BOUND (TXU)
*         L=2  TRANSPORT CHANNEL 'X' LOWER BOUND (TXL)
*         L=3  TRANSPORT COST ON CHANNEL (QTX)
*
*        CCCC      GGGG      YYYY      PP           -TXU--  -TXL--  -QTX--
*TCXP    TCOA      PEAK      1990      01           010000  000000  0.0100
*TCXP    TCOA      PEAK      1990      02           010000  000000  0.0100
```

```
PIMP        SWAW       1990          01           0000.4  0000.1  0009.0  0000.0  0000.0
PIMP        SWAW       1990          02           0000.4  0000.1  0009.0  0000.0  0000.0
PIMP        SWAW       1990          03           0000.4  0000.1  0009.0  0000.0  0000.0
*
*   PEXG   *** POWER EXPORT GENERAL DATA ***
*          J=1
*
*          EXPORT        AMOUNT
*        --------        ------
PEXG        SWAW          0000.0
PEXG        MAPU          0000.0
*
*   PEXY   *** POWER EXPORT YEAR DATA ***
*          K=1 ENERGY EXPORT UPPER BOUND   (EEU)  (GWH)
*          K=2 ENERGY EXPORT LOWER BOUND   (EEL)  (GWH)
*
*          EXPORT      YEAR             EEU      EEL
*        -------- --------           ------   ------
PEXY        SWAW       1990          3500.0   0000.0
PEXY        MAPU       1990          000000   1000.0
*
*   PEXP   *** POWER EXPORT PERIOD DATA ***
*          N=1  POWER EXPORT UPPER BOUND  (PEU)
*          N=2  POWER EXPORT LOWER BOUND  (PEL)
*          N=3  COST OF POWER EXPORT  (QPE)
*          N=4  ENERGY EXPORT UPPER BOUND   (EEU)  (GWH)
*          N=5  ENERGY EXPORT LOWER BOUND   (EEL)  (GWH)
*
*          EXPORT      YEAR  PERIODS            PEU      PEL      QPE      EEU      EEL
*        -------- -------- --------          ------   ------   ------   ------   ------
PEXP        SWAW       1990          01          0001.0   0000.5   12.000   0000.0   0000.0
PEXP        SWAW       1990          02          0001.0   0000.5   12.000   2000.0   0000.0
PEXP        SWAW       1990          03          0001.0   0000.5   12.000   0000.0   0000.0
PEXP        MAPU       1990          01          0001.0   0000.5   10.000   0000.0   0000.0
PEXP        MAPU       1990          02          0001.0   0000.5   10.000   0000.0   0000.0
PEXP        MAPU       1990          03          0001.0   0000.5   10.000   0000.0   0000.0
*
*   COLG   *** COLLIERY GENERAL DATA ***
*          J=1
*
*       CCCC             ------
*COLG    TCOA              000000
*
*   COLY   *** COLLIERY YEAR DATA ***
*          N=1  COLLIERY OUTPUT UPPER BOUND (COU)
*          N=2  COLLIERY OUTPUT LOWER BOUND(COL)
*          N=3  COLLIERY OUTPUT COST (QCO)
*          N=4  CALORIFIC VALUE  (CVL)  (MJ/KG)
*          N=5               CVR
*
*          CCCC       YYYY            -COU--  -COL--  -QCO--  -CVL--  -CVR--
*COLY      TCOA        1990            900000  000200  0.2000  0.3600  1.0000
*COLY      TCOA        1991            900000  000000  0.2000  0.3600  1.0000
*COLY      OPTI        1990            900000  000000  0.3000  0.7200  1.0000
*COLY      OPTI        1991            900000  000000  0.3000  0.7200  1.0000
*COLY      DUVA        1990            900000  000000  0.5000  0.1800  1.0000
```

```
STAP        UNEN      1990          02    2  0000.0  0000.0  1.0000  0001.0  0000.0
STAP        UNEN      1990          03    2  0000.0  0000.0  1.0000  0001.0  0000.0
STAP        PEAK      1990          01    2  0000.0  1028.2  1.0000  0001.0  0000.0
STAP        PEAK      1990          02    2  0000.0  1088.6  1.0000  0001.0  0000.0
STAP        PEAK      1990          03    2  0000.0  1028.2  1.0000  0001.0  0000.0
STAP        MDMT      1990          01    2  0000.0  1265.2  1.0000  0001.0  0000.0
STAP        MDMT      1990          02    2  0000.0  1366.8  1.0000  0001.0  0000.0
STAP        MDMT      1990          03    2  0000.0  1265.2  1.0000  0001.0  0000.0
STAP        BASE      1990          01    2  0000.0  0000.0  1.0000  0001.0  0000.0
STAP        BASE      1990          02    2  0000.0  0000.0  1.0000  0001.0  0000.0
STAP        BASE      1990          03    2  0000.0  0000.0  1.0000  0001.0  0000.0
*
*       STATION     YEAR  PERIODS  SEQ    RAX     PLL     IPC     PSI
*      --------  -------- -------- ----  ------  ------  ------  ------
STAP        UNEN      1990          01    3  0000.0  0000.0  0001.0  0010.0
STAP        UNEN      1990          02    3  0000.0  0000.0  0001.0  0010.0
STAP        UNEN      1990          03    3  0000.0  0000.0  0001.0  0010.0
STAP        PEAK      1990          01    3  0000.0  0000.0  0000.0  0000.0
STAP        PEAK      1990          02    3  0000.0  0000.0  0000.0  0000.0
STAP        PEAK      1990          03    3  0000.0  0000.0  0000.0  0000.0
STAP        MDMT      1990          01    3  0000.0  0000.0  0000.0  0000.0
STAP        MDMT      1990          02    3  0000.0  0000.0  0000.0  0000.0
STAP        MDMT      1990          03    3  0000.0  0000.0  0000.0  0000.0
STAP        BASE      1990          01    3  0000.0  0000.0  0000.0  0000.0
STAP        BASE      1990          02    3  0000.0  0000.0  0000.0  0000.0
STAP        BASE      1990          03    3  0000.0  0000.0  0000.0  0000.0
*
*  PIMG   *** POWER IMPORT GENERAL DATA ***
*         J=1
*
*         IMPORT       AMOUNT
*      --------        ------
PIMG        CAHB       0000.0
PIMG        SWAW       0000.0
*
*  PIMY   *** POWER IMPORT YEAR DATA ***
*         K=1 ENERGY IMPORT UPPER BOUND   (EIU)  (GWH)
*         K=2 ENERGY IMPORT LOWER BOUND   (EIL)  (GWH)
*
*         IMPORT      YEAR          EIU     EIL
*      -------- --------        ------  ------
PIMY        CAHB      1990        2500.0  0000.0
PIMY        SWAW      1990        0000.0  0800.0
*
*  PIMP   *** POWER IMPORT PERIOD DATA ***
*         N=1   POWER IMPORT UPPER BOUND   (PIU)  (GW)
*         N=2   POWER IMPORT LOWER BOUND   (PIL)  (GW)
*         N=3   COST OF POWER IMPORT   (QPI)  (RM/GW)
*         N=4   ENERGY IMPORT UPPER BOUND   (EIU)  (GWH)
*         N=5   ENERGY IMPORT LOWER BOUND   (EIL)  (GWH)
*
*         IMPORT      YEAR  PERIODS           PIU     PIL     QPI     EIU     EIL
*      -------- -------- --------        ------  ------  ------  ------  ------
PIMP        CAHB      1990         01      0000.5  0000.1  0007.0  0000.0  0000.0
PIMP        CAHB      1990         02      0000.5  0000.1  0007.0  0000.0  0000.0
PIMP        CAHB      1990         03      0000.5  0000.1  0007.0  0000.0  0000.0
```

APPENDIX F

REPORT EXAMPLE

The first three pages of the report in this apendix lists the result of the study.

PROBLEM NAME	:	KOPT-SD1 (TEST-RX OPTIMISATION STUDY SCENARIO D CASE 1)
PROBLEM VERSION	:	KOPT-SD1
SOLUTION STATUS	:	OPTIMAL
OBJECTIVE FUNCTION	:	5674.877209957
NUMBER OF ITERATIONS	:	25991
NUMBER OF ROWS	:	15077
NUMBER OF COLUMNS	:	16702
STUDY PERIOD	:	START 1993 ENDS 1998
NUMBER OF PERIODS	:	13
NUMBER OF SLICES	:	9
NUMBER OF STATIONS	:	18
NUMBER OF COLLIERIES	:	17
NUMBER OF IMPORTS	:	1
NUMBER OF EXPORTS	:	1
NUMBER OF RESOURCES	:	2
NUMBER OF TRANSPORT LINKS	:	17

The remaider of the report tables the details of the study performed, as indexed below.

```
            GO TO 500
          ENDIF
         GO TO 500
C
C
 400      GOUT = 'N'
             IF (RANGEV(NAME,2,2)(3:3) .EQ. GOUT) THEN
                READ (RANGEV(NAME,NNN,2)(4:5),'(I2)') NPLANT
                WRITE(RANGEV(NAME,NNN,2)(1:8),'(A8)') KPNAME(NPLANT)
               IF (NNN .EQ. 1) GOTO 210
               IF (NNN .EQ. 2) GOTO 250
             ELSE
                READ (RANGEV(NAME,NNN,2)(2:3),'(I2)') NPLANT
                WRITE(RANGEV(NAME,NNN,2)(1:8),'(A8)') KPNAME(NPLANT)
               IF (NNN .EQ. 1) GOTO 210
               IF (NNN .EQ. 2) GOTO 250
             ENDIF
 410      READ (RANGEV(NAME,NNN,2)(2:3),'(I2)') NPLANT
            WRITE(RANGEV(NAME,NNN,2)(1:8),'(A8)') KPNAME(NPLANT)
          IF (NNN .EQ. 1) GOTO 210
          IF (NNN .EQ. 2) GOTO 250
 420      READ (RANGEV(NAME,NNN,2)(2:3),'(I2)') NPLANT
            WRITE(RANGEV(NAME,NNN,2)(1:8),'(A8)') KCNAME(NPLANT)
          IF (NNN .EQ. 1) GOTO 210
          IF (NNN .EQ. 2) GOTO 250


9999     CONTINUE
         CLOSE(13)
C        STOP
         RETURN
         END
C
```

```
500  READ(13,200,END=9999) NU
200  FORMAT (A132)
           IF (NU(11:16) .EQ. COLUMN) GOTO 9999
       IF (NU(10:11) .EQ. GL) THEN
         NAME = NAME + 1
C
         NNN  = 1
         WRITE (RANGEV(NAME,1,1)(1:8),'(A8)') NU(10:17)
         WRITE (RANGRV(NAME,2,1)(1:8),'(A8)') NU(10:17)
            READ(NU(7 :87),'(F14.0)') RANGER(NAME,1)
         WRITE (RANGEV(NAME,1,2)(1:8),'(A8)') NU(122:129)
C
                GOUT = 'G'
           IF (RANGEV(NAME,1,2)(1:1) .EQ. GOUT) GOTO 400
                GOUT = 'P'
           IF (RANGEV(NAME,1,2)(1:1) .EQ. GOUT) GOTO 410
                GOUT = 'C'
           IF (RANGEV(NAME,1,2)(1:1) .EQ. GOUT) GOTO 420
 210     WRITE (RANGEV(NAME,1,3)(1:2),'(A2)') NU(131:132)
C
         WRITE (RANGEV(NAME,1,3)(1:2),'(A2)') NU(131:132)
C
C
C
C    ---  READ THE UPPER ACTIVITY  ---
     READ(13,200,END=9999) NU
                NNN = 2
C
            READ(NU(74:87),'(F14.0)') RANGER(NAME,2)
         WRITE (RANGEV(NAME,2,2)(1:8),'(A8)') NU(122:129)
C
                GOUT = 'G'
           IF (RANGEV(NAME,2,2)(1:1) .EQ. GOUT) GOTO 400
                GOUT = 'P'
           IF (RANGEV(NAME,2,2)(1:1) .EQ. GOUT) GOTO 410
                GOUT = 'C'
           IF (RANGEV(NAME,2,2)(1:1) .EQ. GOUT) GOTO 420
C
 250     WRITE (RANGEV(NAME,2,3)(1:2),'(A2)') NU(131:132)
C
C
C
C    ---  READ A BLANK LINE  ---
     READ(13,200,END=9999) NU
                READ(NU(1:1),'(I1)') NEWPG
                IF (NEWPG .EQ. 1) GOTO 95
C
```

```
C
      END
C
C ######################################################################
      SUBROUTINE RANGES (RANGEV,RANGER)
C     ========== ======
C..   - used parameters to dimension local arrays
C..
C
%INCLUDE 'MGCOMS.I'
%INCLUDE 'RWCOMM.I'
C
      CHARACTER *132 NU
      CHARACTER *6   NUMBER
      CHARACTER *3   ROW
      CHARACTER *6   COLUMN
      CHARACTER *3   GL
      CHARACTER *1   GOUT
      CHARACTER *10  RANGEV (100,2,4)
C
      REAL RANGER(100,2)
C
      OPEN (13,FILE='ran',STATUS='OLD')
C
      NUMBER = 'NUMBER'
      ROW    = 'ROW'
      GL     = 'GL'
      COLUMN = 'COLUMN'
C
        DO 50 NI = 1,100
        DO 60 NJ = 1,2
         DO 70 NK = 1,4
          RANGEV (NI,NJ,NK) = ' '
 70      CONTINUE
         RANGER(NI,NJ) = 0.0
 60     CONTINUE
 50     CONTINUE
C
            NAME = 0
C
C
 95   READ(13,100,END=9999) NU
 100  FORMAT (A132)
         IF (NU(2:7) .EQ. NUMBER) THEN
           IF (NU(12:14) .EQ. ROW) GOTO 500
         END IF
       GOTO 95
C
```

```
9225  FORMAT('+',T100)
C
      WRITE(KPRINT,9050)
C
      END
C
C ====================############=======================
C
      SUBROUTINE SHADOW (TYPE,NUMPRD,NPRD,YY)
C
C       THIS SUBROUTINE WRITES OUT THA TABLE HEADINGS
C                                AND
C        THIS WRITES OUT THE TITLE OF THE
C        PROBLEM(50-CHARACTERS LONG) AND THE VERSION
C
%INCLUDE 'MGCOMS.I'
%INCLUDE 'RWCOMM.I'
C
      INTEGER TYPE,NUMPRD,NPRD,YY
C
      WRITE(KPRINT,9040)
9040  FORMAT('1',120(1H-))
      WRITE(KPRINT,9050)
9050  FORMAT(1X,120(1H-))
C
      WRITE(KPRINT,9100)KTTLE,KVERS
9100  FORMAT(' # ===  ',A,'=== STUDY CODE : ',A,T100)
C
C  =====***===TABLE NAME===***=========
        WRITE(KPRINT,9150) KYNAME(YY),OBJVAL
9150  FORMAT(1X,'#',T2,'=== SHADOW PRICE OF DEMAND EQUATION ===',
     + T61,'YEAR : ',A,T91,'OBJECTIVE VALUE : R',F12.2,T100)
C
C
C
C  =====***===TABLE NAME===***=========
      WRITE(KPRINT,9200) BDPN,BDBN
9200  FORMAT(1X,'=== INSTALLED CAPACITIES (kW) ===',5X,'PEAK LOAD :',
     +          F10.2,5X,'BASE LOAD :',F10.2)
C
C
C
      WRITE(KPRINT,9220) (KSNAME(I),I=NUMPRD,NPRD)
9220  FORMAT(1X,'#  NAME    #      ',10(1X,A))
      WRITE(KPRINT,9225)
9225  FORMAT('+',T100)
C
      WRITE(KPRINT,9050)
```

```
C                           AND
C       THIS WRITES OUT THE TITLE OF THE
C       PROBLEM(50-CHARACTERS LONG) AND THE VERSION
C
%INCLUDE 'MGCOMS.I'
%INCLUDE 'RWCOMM.I'
C
      INTEGER TYPE,NUMPRD,NPRD
C
      WRITE(KPRINT,9040)
9040  FORMAT(//,1X,120(1H-))
      WRITE(KPRINT,9050)
9050  FORMAT(1X,120(1H-))
C
      WRITE(KPRINT,9100)KTTLE,KVERS
9100  FORMAT(1X,'# ===   ',A,'=== STUDY CODE --',A,T100)
C
C  =====***===TABLE NAME===***=========
       IF (TYPE .EQ. 1)THEN
C         WRITE(KPRINT,9150) KYNAME(YY)
C9150  FORMAT(1X,'#',T2,'=== POWER OUTPUT ===',
C     +                T61,'YEAR ',A,T100)
C
       ENDIF
C       IF (TYPE .EQ. 2) THEN
C       WRITE(KPRINT,9160) KYNAME(YY)
C9160  FORMAT(1X,'#',T2,'=== PUMPSTORAGE LOAD ===',
C     +                T61,'YEAR ',A,T100)
C      ENDIF
C
       IF (TYPE .EQ. 3)THEN
        WRITE(KPRINT,9170)
9170  FORMAT(1X,'#',T2,'=== COAL OUTPUT (KTONS)===',T100)
       ENDIF
C
C  =====***===TABLE NAME===***=========
      WRITE(KPRINT,9200)
9200  FORMAT(1X,'# COLLIERY #',42(1H=),' YEARS ',43(1H=),T100)
C
      IF (NPRD . EQ. NY) THEN
          WRITE(KPRINT,9210)
9210  FORMAT('+',T106,'# ANNUAL TOTAL #')
      ENDIF
C
C
      WRITE(KPRINT,9220) (KYNAME(I),I=NUMPRD,NPRD)
9220  FORMAT(1X,'#  NAME     #',10(1X,A))
      WRITE(KPRINT,9225)
```

```
      INTEGER TYPE,NUMPRD,NPRD,YY
C
      WRITE(KPRINT,9040)
9040  FORMAT(//,1X,120(1H-))
      WRITE(KPRINT,9050)
9050  FORMAT(1X,120(1H-))
C
      WRITE(KPRINT,9100)KTTLE,KVERS
9100  FORMAT(1X,'# ===  ',A,'=== STUDY CODE : ',A,T100)
C
C  =====***===TABLE NAME===***=========
       IF (TYPE .EQ. 1)THEN
        WRITE(KPRINT,9150) KYNAME(YY)
9150  FORMAT(1X,'#',T2,'=== POWER OUTPUT (GWH) ===',
     +              T61,'YEAR ',A,T100)
C
       ENDIF
       IF (TYPE .EQ. 2) THEN
       WRITE(KPRINT,9160) KYNAME(YY)
9160  FORMAT(1X,'#',T2,'=== PUMPSTORAGE LOAD (GWH) ===',
     +              T61,'YEAR ',A,T100)
       ENDIF
C
C
C  =====***===TABLE NAME===***=========
      WRITE(KPRINT,9200)
9200  FORMAT(1X,'# STATION  #',42(1H=),' PERIODS ',41(1H=),T100)
C
      IF (NPRD . EQ. NP) THEN
          WRITE(KPRINT,9210)
9210  FORMAT('+',T106,'# ANNUAL TOTAL #')
      ENDIF
C
C
      WRITE(KPRINT,9220) (KTNAME(I),I=NUMPRD,NPRD)
9220  FORMAT(1X,'#  NAME     #         ',10(1X,A))
      WRITE(KPRINT,9225)
9225  FORMAT('+',T100)
C
      WRITE(KPRINT,9050)
C
      END
C
C==================############# ========================
C
      SUBROUTINE CTHEAD (TYPE,NUMPRD,NPRD)
C
C       THIS SUBROUTINE WRITES OUT THA TABLE HEADINGS
```

```
CC
C               WRITE (KPRINT,4165) (RANGEY(KK,1),KK=NUMSLC,NSLC)
C               WRITE (KPRINT,4145)
C               WRITE (KPRINT,4167) (RANGEY(KK,2),KK=NUMSLC,NSLC)
C               WRITE (KPRINT,4145)
C
C
C
C4095   CONTINUE
C
4140  FORMAT(1X,'# ','=PERIOD=',T13,'#',' --- SHADOW PRICE (R/kWH) ---'
     *         ,T100,//,1X,'# ',A,T13,'#',10(1X,F8.2))
4145  FORMAT ('+',T100)
4165  FORMAT (1X,'# RANGE LL',T13,'#',10(1X,F8.2))
4167  FORMAT (1X,'# RANGE UL',T13,'#',10(1X,F8.2))
C
        NUMSLC = NUMSLC + 10
4100  CONTINUE
C
4090  CONTINUE
C
4000  CONTINUE
C
C
C
C


C##################################
C
       WRITE (KPRINT,6969)
6969   FORMAT ('1',1X,//'***  DUMMY PAGE  ***')
       WRITE (KPRINT,6969)
       RETURN
       END
C
C ======================#############=========================
C
      SUBROUTINE TBHEAD (TYPE,NUMPRD,NPRD,YY)
C
C       THIS SUBROUTINE WRITES OUT THA TABLE HEADINGS
C                             AND
C      THIS WRITES OUT THE TITLE OF THE
C      PROBLEM(50-CHARACTERS LONG) AND THE VERSION
C
%INCLUDE 'MGCOMS.I'
%INCLUDE 'RWCOMM.I'
C
```

```
     +        1X,'# ',T13,'#',10(1X,F8.2))
9876  FORMAT (
     +        1X,'# ','#PERIOD',T13,'#',' --- (HRS) ---',T100,/,
     +        1X,'# ',T13,'#',10(1X,F8.2))
C  ====****=== SORTING THE RANGES ===****====
C
C        DO 4160 K = NUMSLC,NSLC
CC
CC
C          DO 4170 KL =1,100
C       IF((RANGER(KL,  .EQ. 0.0).AND.(RANGER(KL,2).EQ. 0.0))GOTO 4170
C         READ(RANGEV(KL,1,1)(3:3),'(I1)') IIA
C         READ(RANGEV(KL,1,1)(4:5),'(I2)') IJA
C         READ(RANGEV(KL,1,1)(6:7),'(I2)') IKA
CC
C       IF((IIA .LE. II) .AND. (IJA .LE. IJ) .AND. (IKA .LE. K))THEN
C         WRITE (RANGEX(K,1)(1:8),'(F8.3)') RANGER(KL,1)
C         WRITE (RANGEX(K,2)(1:8),'(A8)') RANGEV(KL,1,2)(1:8)
C         WRITE (RANGEX(K,3)(1:5),'(3X,A2,3X)') RANGEV(KL,1,3)(1:2)
C         WRITE (RANGEX(K,4)(1:8),'(F8.3)') RANGER(KL,2)
C         WRITE (RANGEX(K,5)(1:8),'(A8)') RANGEV(KL,2,2)(1:8)
C         WRITE (RANGEX(K,6)(1:5),'(3X,A2,3X)') RANGEV(KL,2,3)(1:2)
C       ENDIF
CC
C4170      CONTINUE
CC
C4160   CONTINUE
CC
CC ================================================================
CC ******    WRITE OUT RANGE INFORMATION FOR EACH PERIOD
C       WRITE (KPRINT,4230)
CC
C4230   FORMAT (1X,'# ',T13,'#',T100)
CC             DO 4180 KL = 1,6
CC               WRITE (KPRINT,4165) (RANGEX(KK,KL)(1:8),KK=NUMSLC,NSLC)
CC               WRITE (KPRINT,4145)
CC4180         CONTINUE
C              DO 4995 KKK = NUMSLC,NSLC
C                READ (RANGEX(KKK,1)(1:8),'(F8.3)') RANGEY(KKK,1)
C                READ (RANGEX(KKK,4)(1:8),'(F8.3)') RANGEY(KKK,2)
C4995          CONTINUE
CC
C               WRITE (KPRINT,4165) ((RANGEY(KK,1) - (SDM(II,IJ,KK,2)*
C     +                   PDM(II,IJ,2)*DMD(II,2))),KK=NUMSLC,NSLC)
C               WRITE (KPRINT,4145)
C               WRITE (KPRINT,4167) ((RANGEY(KK,2) - (SDM(II,IJ,KK,2)*
C     +                   PDM(II,IJ,2)*DMD(II,2))),KK=NUMSLC,NSLC)
C               WRITE (KPRINT,4145)
```

```
C
C4243  FORMAT (1X,'# ',A,T13,'#',10(1X,F8.2))
C4297  CONTINUE
C
C =======================================================
C        WRITE OUT EACH POWER EXPORT
C      WRITE (KPRINT,4390)
C
C4390  FORMAT (1X,'# ',T13,'#',T100,/,
C    +        1X,'# ','POWER EX',T13,'#',' --- (MW) ---',T100)
C
C      DO 4397 IJP = 1,NI
C
C      WRITE (KPRINT,4343) KENAME(IJP),(BEPE(IJP,II,IJ,K),K=NUMSLC,NSLC)
C      WRITE (KPRINT,4145)
C
C4343  FORMAT (1X,'# ',A,T13,'#',10(1X,F8.2))
C4397  CONTINUE
C
C  =====================================================
C        WRITE OUT EACH STATIONS PUMPING LOAD
C
      WRITE (KPRINT,4200)
C
4200  FORMAT (1X,'# ',T13,'#',T100,/,
     +        1X,'#',' PMP LOAD',T13,'#',' --- (kW) ---',T100)
      DO 4210 IJP = 1,NG
C
C                IF (POWR1(IJP,2) .NE. 1.0)GOTO 4210
C
               SUM = 0.
      DO 4202 L = NUMSLC,NSLC
               SUM = SUM + BLPL(IJP,II,IJ,L)
4202  CONTINUE
      IF (SUM.GT.0.000001) THEN
      WRITE (KPRINT,4143) KGNAME(IJP),(BLPL(IJP,II,IJ,K),K=NUMSLC,NSLC)
      WRITE (KPRINT,4145)
      END IF
C
4210  CONTINUE
C
C        WRITE OUT DEMAND FOR EACH SLICE
      WRITE (KPRINT,4142) (DMCS(II,IJ,K),K=NUMSLC,NSLC)
      WRITE (KPRINT,9876) (SWH(II,IJ,K),K=NUMSLC,NSLC)
      WRITE (KPRINT,4145)
C
4142  FORMAT (
     +        1X,'# ','#DEMAND',T13,'#',' --- (kW) ---',T100,/,
```

```
      ELSE
        NSLC =NSLC +10
      ENDIF
C
C ====***=== WRITING TABLE HEADINGS ===***===
C
           CALL SHADOW (TYPE,NUMSLC,NSLC,II)
C
C ====***=== GETTING RANGES ===***===
C          CALL RANGES (RANGEV,RANGER)
C
C
C
C
C ==========================================================
C       WRITE OUT INFORMATION OF SHADOW PRICE FOR EACH SLICE
C
     WRITE (KPRINT,4140) KPNAME(IJ),
    +        ((-1.0 * (PGL(II,IJ,K))
    +        /(SWH(II,IJ,K)*PLW(II,IJ,1))),K=NUMSLC,NSLC)
     WRITE (KPRINT,4145)
C
C
C =======================================================
C       WRITE OUT EACH STATIONS GENERATION OUTPUT
     WRITE (KPRINT,4190)
C
4190 FORMAT (1X,'# ',T13,'#',T100,/,
    +       1X,'# ','STN OUTP',T13,'#',' --- (kW) ---',T100)
C
     DO 4097 IJP = 1,NG
C
     WRITE (KPRINT,4143) KGNAME(IJP),(BGO(IJP,II,IJ,K),K=NUMSLC,NSLC)
     WRITE (KPRINT,4145)
C
4143 FORMAT (1X,'# ',A,T13,'#',10(1X,F8.2))
4097 CONTINUE
C
C =======================================================
C       WRITE OUT EACH POWER IMPORT
C     WRITE (KPRINT,4290)
C
C4290 FORMAT (1X,'# ',T13,'#',T100,/,
C   +        1X,'# ','POWER IP',T13,'#',' --- (MW) ---',T100)
C
C     DO 4297 IJP = 1,NI
C
C     WRITE (KPRINT,4243) KINAME(IJP),(BIPI(IJP,II,IJ,K),K=NUMSLC,NSLC)
C     WRITE (KPRINT,4145)
```

```
C        "TYPE" SPECIFIES WHICH TABLE IS BEING PRINTED
            TYPE = 3
C         CALL CTHEAD (TYPE,NUMPRD,NPRD)
C
      DO 3110 IK = 1,NC
C
      DO 3120 I = NUMPRD,NPRD
C
C      TOPRGO(IK) = BCO(IK,I) + TOPRGO(IK)
3120  CONTINUE
C        WRITE OUT INFORMATION FOR EACH COLLIERY
C      WRITE (KPRINT,3140) KCNAME(IK),(BCO(IK,K),K=NUMPRD,NPRD)
      WRITE (KPRINT,3145)
3140  FORMAT (1X,'# ',A,T13,'#',10(1X,F8.3))
3145  FORMAT ('+',T100)
C
      IF (NPRD .EQ. NY) THEN
       WRITE(KPRINT,3150) TOPRGO(IK)
3150  FORMAT ('+',T110,'#',1X,F8.3,T100)
      ENDIF
3110  CONTINUE
        NUMPRD = NUMPRD + 10
3100  CONTINUE
3090  CONTINUE
C
      CONTINUE
C
C
C  ===================SHADOW PRICE==============================
C
C       ===***=== START PRINTING THE TABLE ===***===
C                 INITIALISING VARIABLES
      NSLC   = 0
      NUMSLC = 0
      NUYR   = 0
      TYPE   = 0
C
C
      DO 4000 II = 1,NY
C
      DO 4090 IJ = 1,NP
C
        NSLC   = 0
        NUMSLC = 1
C
      DO 4100 IK = 1,NS,10
       IF ((NSLC+10) .GE. NS) THEN
         NSLC = NS
```

#	#	PERIOD 02									#	(GWH)	#
# STM OUTP	# --- (GW) --- (+)												#
# ABWT	#	1.122	1.122	1.122	1.122	1.122	1.122	1.122	1.122	1.122	#	754.	#
# CAND	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# DUVA	#	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	#	1348.	#
# GRT7	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# HEMG	#	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.471	#	1010.	#
# KRMD	#	0.723-	0.723-	0.723-	0.723-	0.948	0.723-	0.723-	0.723-	0.723-	#	507.	#
# KRIL	#	1.888	1.888	1.888	1.888	0.830-	0.830-	1.803	1.258	0.830-	#	915.	#
# LTBQ	#	2.998	2.998	2.998	2.998	2.998	2.998	2.998	2.998	2.998	#	2015.	#
# MAJU	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# MATI	#	2.904	2.904	2.904	2.904	2.904	2.904	2.904	2.904	2.141-	#	1872.	#
# MTLA	#	1.955	1.955	1.955	1.955	1.955	1.955	1.955	1.955	1.955	#	1314.	#
# SRMG	#	0.206+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	1.	#
# TUTU	#	3.016	3.016	3.016	3.016	3.016	2.279	1.088-	1.088-	1.088-	#	1378.	#
# KORB	#	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	#	584.	#
# HVYK	#	0.508+	0.000-	0.508+	0.000-	0.337	0.508+	0.000-	0.000-	0.000-	#	97.	#
# DRAK	#	0.644	0.667+	0.000-	0.000-	0.208	0.000-	0.000-	0.000-	0.000-	#	44.	#
# PALM	#	0.000-	0.371	0.260	0.220	0.000-	0.000-	0.000-	0.000-	0.000-	#	50.	#
# GTBS	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# POWER IP	# --- (GW) --- (+)												#
# SWAN	#	0.100+	0.100+	0.000-	0.100+	0.000-	0.031	0.000-	0.000-	0.000-	#	16.	#
#	#												#
# POWER EX	# --- (GW) --- (-)												#
# KEP1	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# PMP LOAD	# --- (GW) --- (-)												#
# DRAK	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.132	0.667+	0.667+	0.667+	#	217.	#
# PALM	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.267	0.378+	#	67.	#
#	#												#
# SP RES RL	# --- (GW) --- (+)												#
#	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.303-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# SDEMAND	# --- (GW) --- (=)												#
#	#	20.447	20.126	19.756	19.388	18.693	17.601	16.309	15.497	14.158	#	11628.	#

# MAJU	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# MATI	#	2.997	2.141-	2.997	2.141-	2.997	2.997	2.141-	2.141-	2.141-	#	1630.	#
# MILA	#	2.844	2.844	2.844	2.844	2.844	2.844	2.844	1.077	1.026-	#	1538.	#
# SRNG	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# TUTU	#	1.088-	3.016	3.016	2.211	1.088-	1.088-	1.088-	1.088-	1.088-	#	1025.	#
# KOHB	#	1.060-	1.060-	1.060-	1.060-	1.060-	1.060-	1.060-	1.060-	1.060-	#	712.	#
# HVVK	#	0.000-	0.508+	0.508+	0.487	0.000-	0.000-	0.000-	0.000-	0.000-	#	97.	#
# DRAK	#	0.667+	0.326	0.000-	0.000-	0.000-	0.000-	0.000-	0.296	0.000-	#	44.	#
# PALM	#	0.378+	0.000-	0.000-	0.378+	0.099	0.000-	0.000-	0.000-	0.000-	#	50.	#
# GTBS	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												
# POWER IP	# ---	(GW)	--- (+)										
# SHAW	#	0.100+	0.100+	0.100+	0.000-	0.000-	0.000-	0.000-	0.062	0.000-	#	16.	#
#	#												#
# POWER EX	# ---	(GW)	--- (-)										#
# EXP1	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# PMP LOAD	# ---	(GW)	--- (-)										#
# DRAK	#	0.000-	0.000-	0.667+	0.000-	0.000-	0.000-	0.667+	0.364	0.667+	#	217.	#
# PALM	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.378+	0.035	0.000-	0.378+	#	67.	#
#	#												#
# SP RES RLS	---	(GW)	--- (+)										#
#	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# SDEMAND	# ---	(GW)	--- (=)										#
#	#	20.172	19.855	19.490	19.049	18.441	17.364	16.089	15.288	13.967	#	11464.	#

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 2.2 ===

=== SYSTEM MAINTENANCE (GW) === YEAR 1993

STATION NAME	PERIODS 1	2	3	4	5	6	7	8	9	10
UPP BND	2.800	5.600	5.600	5.600	5.600	5.600	5.600	5.600	5.600	5.600
VALUE	2.800	5.443	5.600	5.142	5.600	4.183	4.113	4.515	3.530	5.004
LOW BND	0.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 2.2 ===

=== SYSTEM MAINTENANCE (GW) === YEAR 1993

STATION NAME	PERIODS 11	12	13
UPP BND	5.600	5.600	2.800
VALUE	4.102	5.600	2.800
LOW BND	2.000	2.000	0.000

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 3 ===

=== POWER - OUTPUT/IMPORT/EXPORT/PUMP LOAD/SPIN RESERVE RELAX/DEMAND === YEAR 1993

STATION NAME	SLICES 1	2	3	4	5	6	7	8	9	(GWH)
	PERIOD 01									
STN OUTP --- (GW) --- (+)										
ARNT	1.295	1.564	1.336	1.631	1.631	1.631	1.631	1.631	1.631	1075.
CAND	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DOVA	2.917	2.917	2.917	2.917	2.917	2.917	2.917	2.917	2.917	1960.
GRIV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HRND	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	751.
KRND	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	486.
KRIL	2.276	0.830-	0.830-	0.830-	1.255	0.830-	0.830-	0.830-	0.830-	604.
LYBO	2.710	2.710	2.710	2.710	2.710	2.535	2.441	2.710	2.479	1758.

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=== KOPT-SD1 (TEST-RI OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 2.1 ===

=== PLANNED OUTAGE (pu) === YEAR 1993

STATION NAME	1	2	3	4	5	6	7	8	9	10
ARNT	0.030	0.333	0.298	0.030	0.333	0.030	0.030	0.036	0.030	0.043
DUVA	0.030	0.333	0.333	0.333	0.333	0.123	0.333	0.030	0.038	0.064
HEMD	0.300	0.055	0.055	0.055	0.055	0.300	0.300	0.300	0.087	0.300
KEND	0.050	0.050	0.050	0.050	0.132	0.050	0.241	0.530	0.050	0.342
KRIL	0.040	0.204	0.333	0.040	0.333	0.040	0.048	0.044	0.040	0.101
LTBO	0.123	0.030	0.030	0.241	0.037	0.333	0.030	0.333	0.317	0.030
MATI	0.120	0.051	0.300	0.300	0.300	0.300	0.238	0.159	0.047	0.300
MTLA	0.030	0.333	0.030	0.030	0.210	0.030	0.030	0.030	0.030	0.180
TUTU	0.030	0.030	0.030	0.060	0.030	0.030	0.030	0.030	0.333	0.209

=== KOPT-SD1 (TEST-RI OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 2.1 ===

=== PLANNED OUTAGE (pu) === YEAR 1993

STATION NAME	11	12	13
ARNT	0.233	0.030	0.030
DUVA	0.030	0.235	0.095
HEMD	0.300	0.113	0.055
KEND	0.050	0.439	0.050
KRIL	0.140	0.040	0.040
LTBO	0.061	0.030	0.030
MATI	0.265	0.300	0.021
MTLA	0.030	0.333	0.030
TUTU	0.129	0.030	0.030

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)         ===  KOPT-SD1                 #
=== TABLE 1.3              ===                                                                         #
=== ENERGY IMPORTED (GWh) ===                          YEAR 1993                                        #
# STATION  #======================================= PERIODS ========================================   #
#  NAME    #      11       12       13                                                                  #
# SWAN     #      16.      16.      16.                                                 #      208.     #
---------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------------
# YEARLY ENERGY IMPORTED            (GWh) #                                             #      208.     #
---------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------------
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)         ===  KOPT-SD1                 #
=== TABLE 1.4              ===                                                                         #
=== ENERGY EXPORTED (GWh) ===                          YEAR 1993                                        #
# STATION  #======================================= PERIODS ========================================   #
#  NAME    #       1        2        3        4        5        6        7        8        9       10  #
---------------------------------------------------------------------------------------------------------
# EXP1     #       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.  #


---------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------------
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)         ===  KOPT-SD1                 #
=== TABLE 1.4              ===                                                                         #
=== ENERGY EXPORTED (GWh) ===                          YEAR 1993                                        #
# STATION  #======================================= PERIODS ========================================   #
#  NAME    #      11       12       13                                                                  #
---------------------------------------------------------------------------------------------------------
# EXP1     #       0.       0.       0.                                                 #        0.     #
---------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------------
# YEARLY ENERGY EXPORTED            (GWh) #                                             #        0.     #
---------------------------------------------------------------------------------------------------------


---------------------------------------------------------------------------------------------------------
```

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)           ===  KOPT-SD1              #
=== TABLE 1.2                ===                                                                    #
=== PUMPSTORAGE LOAD (GWh) ===                          YEAR 1993                                   #
# STATION  #================================== PERIODS ==========================================  #
#  NAME    #      1       2       3       4       5       6       7       8       9      10         #
-----------------------------------------------------------------------------------------------------
# DRAK     #    217.    217.    217.    217.    217.    217.    217.    217.    217.    217.        #
# PALM     #     67.     67.     67.     67.     67.     67.     67.     67.     67.     67.        #
```

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)           ===  KOPT-SD1              #
=== TABLE 1.2                ===                                                                    #
=== PUMPSTORAGE LOAD (GWh) ===                          YEAR 1993                                   #
# STATION  #================================== PERIODS ==========================================  #
#  NAME    #     11      12      13                                                                 #
-----------------------------------------------------------------------------------------------------
# DRAK     #    217.    217.    217.                                                   #    2815.   #
# PALM     #     67.     67.     67.                                                   #     872.   #
-----------------------------------------------------------------------------------------------------
# YEARLY ENERGY PUMPED                 (GWh) #                                         #    3687.   #
-----------------------------------------------------------------------------------------------------
```

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)           ===  KOPT-SD1              #
=== TABLE 1.3                ===                                                                    #
=== ENERGY IMPORTED (GWh) ===                           YEAR 1993                                   #
# STATION  #================================== PERIODS ==========================================  #
#  NAME    #      1       2       3       4       5       6       7       8       9      10         #
-----------------------------------------------------------------------------------------------------
# SWRN     #     16.     16.     16.     16.     16.     16.     16.     16.     16.     16.        #
-----------------------------------------------------------------------------------------------------
```

=== KOPT-SD1 (TEST-RK OPTIMISATION STUDY - SCENARIO D CASE 1) ==== KOPT-SD1
=== TABLE 1,1 === #
=== ENERGY OUTPUT OF EACH STATION (GWh) === YEAR 1993 #

STATION NAME	PERIODS 11	12	13	
ARNT	754.	1096.	925.	12526.
CAMD	0.	0.	0.	0.
DUVA	1810.	1546.	1829.	21464.
GRIV	0.	0.	0.	0.
HEND	751.	952.	1014.	11476.
KEND	550.	542.	486.	7079.
KRIL	1057.	1071.	760.	12719.
LTSO	1950.	2015.	1813.	22567.
MAJU	0.	0.	0.	0.
MATI	1489.	1439.	1530.	19856.
MTLA	1911.	1217.	1598.	22417.
SENG	25.	13.	0.	152.
TUTU	1055.	1549.	1018.	16954.
KOEB	2086.	899.	350.	11789.
RVVA	97.	97.	97.	1266.
DRAK	44.	44.	44.	571.
PALM	50.	50.	50.	654.
GTSS	0.	0.	0.	0.
YEARLY ENERGY GENERATED (GWh)				160490.

=== KOPT-SD1 (TEST-RK OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 1.1 ===

=== ENERGY OUTPUT OF EACH STATION (GWh) === YEAR 1992

STATION NAME	PERIODS 1	2	3	4	5	6	7	8	9	10
ABKT	1075.	754.	793.	1022.	754.	1096.	1096.	1889.	1096.	976.
CAMD	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUVA	1960.	1348.	1348.	1348.	1348.	1771.	1348.	1960.	1957.	1892.
GRTV	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HEND	751.	1010.	1014.	1014.	988.	751.	751.	751.	979.	751.
KEND	486.	507.	487.	511.	641.	527.	711.	545.	546.	539.
KRIL	604.	915.	865.	1133.	780.	1147.	1071.	1224.	1078.	1014.
LTBO	1758.	2015.	1965.	1552.	1978.	1284.	2815.	1284.	1312.	1817.
MAJU	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MATI	1630.	1872.	1439.	1439.	1439.	1439.	1458.	1584.	1661.	1439.
MTLA	1538.	1314.	1742.	1911.	1423.	1911.	1793.	1722.	1722.	1614.
SRNG	0.	1.	14.	21.	1.	8.	35.	35.	1.	0.
TUTU	1025.	1378.	1326.	1209.	1437.	1412.	1737.	1442.	1197.	1168.
KOEB	712.	584.	584.	584.	1167.	1167.	1167.	1167.	1167.	1156.
HVVK	97.	97.	97.	97.	97.	97.	97.	97.	97.	97.
DRAK	44.	44.	44.	44.	44.	44.	44.	44.	44.	44.
PALM	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
GTBS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

: MAJU	Links Station	MAJU	To Colliery	MAJU
: MATI	Links Station	MATI	To Colliery	MATI
: MTLA	Links Station	MTLA	To Colliery	MTLA
: SRVR	Links Station	SRWG	To Colliery	SRVR
: TUT1	Links Station	TUTU	To Colliery	TUT1
: TUT2	Links Station	TUTU	To Colliery	TUT2
: WILG	Links Station	SRWG	To Colliery	WILG

```
NUMBER OF COLLIERIES       :  17
                           : ARNT
                           : CAMD
                           : DUVA
                           : GRTV
                           : HEND
                           : KEN1
                           : KEN2
                           : KRL1
                           : KRL2
                           : LTBO
                           : MAJU
                           : MATI
                           : MTLA
                           : SRVR
                           : TUT1
                           : TUT2
                           : WILG

NUMBER OF IMPORTS          :  1
                           : SWAW

NUMBER OF EXPORTS          :  1
                           : EXP1

NUMBER OF RESOURCES        :  2
                           : KOEB
                           : GTBS

NUMBER OF TRANSPORT LINKS  :  17
                           : ARNT   Links Station   ARNT   To Colliery   ARNT
                           : CAMD   Links Station   CAMD   To Colliery   CAMD
                           : DUVA   Links Station   DUVA   To Colliery   DUVA
                           : GRTV   Links Station   GRTV   To Colliery   GRTV
                           : HEND   Links Station   HEND   To Colliery   HEND
                           : KEN1   Links Station   KEND   To Colliery   KEN1
                           : KEN2   Links Station   KEND   To Colliery   KEN2
                           : KRL1   Links Station   KRIL   To Colliery   KRL1
                           : KRL2   Links Station   KRIL   To Colliery   KRL2
                           : LTBO   Links Station   LTBO   To Colliery   LTBO
```

PROBLEM NAME	:	KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)
PROBLEM VERSION	:	KOPT-SD1
SOLUTION STATUS	:	OPTIMAL
OBJECTIVE FUNCTION	:	5674.877209957
NUMBER OF ITERATIONS	:	25991
NUMBER OF ROWS	:	15077
NUMBER OF COLUMNS	:	16702
STUDY PERIOD	:	START 1993 ENDS 1998
NUMBER OF PERIODS	:	13
NUMBER OF SLICES	:	9
NUMBER OF STATIONS	:	18
	:	ARNT
	:	CAMD
	:	DUVA
	:	GRTV
	:	HEND
	:	KEND
	:	KRIL
	:	LTBO
	:	MAJU
	:	MATI
	:	MTLA
	:	SRWG
	:	TUTU
	:	KOEB
	:	BVVK
	:	DRAK
	:	PALM
	:	GTBS

TABLE 7.1 COST OF COAL MINED/TRANSPORTED (Rm)
TABLE 7.2 COAL STOCKPILES LEVEL/INPUT/OUTPUT [COSTS] (Rm)
TABLE 8 RESOURCE COST (Rm)

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT ...

=== TABLE 4.1

=== AMOUNT OF COAL MINED/TRANSPORTED (MEGA TONS) === OVER STUDY PERIOD

# COL # NAME	# STA # NAME	#	YEARS 1	2	3	4	5	6	#	#
AKNT#	OUTPUT	#	6.180+	6.180+	6.180+	6.180+	6.180+	6.180+	#	37.080
CAMD#	OUTPUT	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000
DUVA#	OUTPUT	#	10.200+	10.200+	10.200+	10.200+	10.200+	10.200+	#	61.200
GRTV#	OUTPUT	#	0.000-	0.000-	0.000-	0.000-	0.029	0.038	#	0.067
HEMD#	OUTPUT	#	6.000+	6.000+	6.000+	6.000+	6.000+	6.000+	#	36.000
KEM1#	OUTPUT	#	4.300-	4.381	7.500+	7.500+	7.500+	7.500+	#	38.681
KEM2	OUTPUT	#	0.000-	0.000-	3.594	3.696	4.740+	4.740+	#	16.770
KRL2	OUTPUT	#	0.000-	2.250+	2.250+	2.250+	2.250+	2.250+	#	11.250
LTBO#	OUTPUT	#	15.120+	15.120+	15.120+	15.120+	15.120+	15.120+	#	90.720
MAJU#	OUTPUT	#	0.800-	1.100-	1.100-	1.100-	1.100-	1.100-	#	6.300
NATI#	OUTPUT	#	10.450-	10.450-	10.450-	11.400-	11.400-	11.400-	#	65.550
MTLA#	OUTPUT	#	10.500+	10.500+	10.500+	10.500+	11.000+	11.000+	#	64.000
SRVR#	OUTPUT	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000
TUT1#	OUTPUT	#	8.000+	8.000+	8.000+	8.000+	8.000+	8.000+	#	48.000
TUT2#	OUTPUT	#	0.000-	0.000-	0.000-	0.000-	2.137	2.200+	#	4.337
WILG#	OUTPUT	#	0.066	0.125	0.125	0.125	0.125	0.125	#	0.692
AKNT#AKNT	TR CH	#	6.180	6.180	6.180	6.180	6.180	6.180	#	37.080
CAMD#CAMD	TR CH	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000
DUVA#DUVA	TR CH	#	10.200	10.200	10.200	10.200	10.200	10.200	#	61.200
GRTV#GRTV	TR CH	#	0.000-	0.000-	0.000-	0.000-	0.029	0.038	#	0.067
HEMD#HEMD	TR CH	#	6.000	6.000	6.000	6.000	6.000	6.000	#	36.000
KEM1#KEMD	TR CH	#	4.300	4.381	7.500	7.500	7.500	7.500	#	38.681
KEM2#KEMD	TR CH	#	0.000-	0.000-	3.594	3.696	4.740	4.740	#	16.773
KRL1#KRIL	TR CH	#	6.500	6.500	6.500	6.500	6.500	6.500	#	39.000
KRL2#KRIL	TR CH	#	0.000-	2.250	2.250	2.250	2.250	2.250	#	11.250
LTBO#LTBO	TR CH	#	15.120	15.120	15.120	15.120	15.120	15.120	#	90.720
MAJU#MAJU	TR CH	#	0.800	1.100	1.100	1.100	1.100	1.100	#	6.300
NATI#NATI	TR CH	#	10.450	10.450	10.450	11.400	11.400	11.400	#	65.550
MTLA#MTLA	TR CH	#	10.500	10.500	10.500	10.500	11.000	11.000	#	64.000
SRVR#SRVG	TR CH	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000
TUT1#TUTU	TR CH	#	8.000	8.000	8.000	8.000	8.000	8.000	#	48.000
TUT2#TUTU	TR CH	#	0.000-	0.000-	0.000-	0.000-	2.137	2.200	#	4.337
WILG#SKAG	TR CH	#	0.066	0.125	0.125	0.125	0.125	0.125	#	0.692

APPENDIX F

#	PERIOD 13									(GWH)
STN OUTP	--- (GW) --- (+)									
ARNT	1.631	1.631	0.589-	1.631	1.631	1.631	1.631	1.631	0.589-	925.
CAMD	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DOVA	2.722	2.722	2.722	2.722	2.722	2.722	2.722	2.722	2.722	1829.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEND	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1014.
KEND	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	486.
KRIL	2.228	2.276	0.830-	2.276	0.830-	0.830-	0.830-	0.830-	0.830-	760.
LTBO	2.998	2.998	2.998	2.998	2.998	2.998	2.443	2.035	2.574	1813.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.141-	2.214	2.141-	2.995	2.141-	2.141-	2.141-	2.141-	2.141-	1530.
MTLA	1.026-	2.844	2.844	2.844	2.844	1.026-	2.844	2.844	1.026-	1598.
SMNG	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
TUTU	3.016	1.088-	3.016	1.088-	1.559	2.935	1.088-	1.088-	1.088-	1018.
KOEB	0.521-	0.521-	0.521-	0.521-	0.521-	0.521-	0.521-	0.521-	0.521-	350.
EVVK	0.508+	0.508+	0.508+	0.000-	0.507	0.000-	0.000-	0.000-	0.000-	97.
DRAK	0.667+	0.000-	0.622	0.000-	0.041	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.000-	0.345	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.378+	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SNAW	0.100+	0.100+	0.100+	0.000-	0.067	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.000-	0.000-	0.000-	0.619	0.000-	0.000-	0.667+	0.667+	0.130	217.
PALM	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.378+	0.267	67.
SP RES BL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
EDEMAND	--- (GW) --- (=)									
	19.790	19.480	19.121	18.688	18.092	17.835	15.785	14.999	13.703	11247.

	PERIOD 12									(GWH)
SYM OUTP	--- (GW) --- (+)									
ARKY	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1096.
CTMD	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVA	2.301	2.301	2.301	2.301	2.301	2.301	2.301	2.301	2.301	1546.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEMD	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417	952.
KEMD	0.723-	0.723-	0.962	0.723-	1.158	0.723-	0.723-	0.723-	0.723-	542.
KRIL	2.276	2.276	2.276	2.276	2.276	1.187	0.830-	1.430	0.830-	1071.
LTBO	2.998	2.998	2.998	2.998	2.998	2.998	2.998	2.998	2.998	2015.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	1439.
MTLA	1.955	1.955	1.955	1.955	1.955	1.955	1.955	1.955	1.826-	1217.
SRMG	0.206+	0.000-	0.206+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	13.
TUTU	3.016	3.016	3.016	3.016	1.906	3.016	2.922	1.088-	1.471	1549.
KOEB	1.337-	1.337-	1.337-	1.337-	1.337-	1.337-	1.337-	1.337-	1.337-	899.
STVK	0.508+	0.508+	0.508+	0.000-	0.507	0.000-	0.000-	0.000-	0.000-	97.
PALM	0.378+	0.378+	0.000-	0.353	0.000-	0.000-	0.000-	0.000-	0.000-	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SMAW	0.024	0.010	0.100+	0.000-	0.100+	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAX	0.000-	0.000-	0.000-	0.000-	0.000-	0.132	0.667+	0.667+	0.667+	217.
PALM	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.378+	0.000-	0.267	67.
SP RES RL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DEMAND	--- (GW) --- (=)									
	21.579	21.240	20.849	20.377	19.727	18.575	17.211	16.354	14.941	12263.

	PERIOD 11									(GWH)
SIM OUTP	--- (GW) --- (+)									
ARNT	1.122	1.122	1.122	1.122	1.122	1.122	1.122	1.122	1.122	754.
CAND	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVA	2.917	2.917	2.917	2.917	2.917	2.917	2.917	2.917	1.471	1810.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
EEMD	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	751.
KEND	1.962	1.963	0.723-	0.723-	0.927	0.723-	0.723-	0.723-	0.723-	550.
KRIL	2.040	2.040	2.040	2.040	2.040	2.040	1.441	0.830-	0.830-	1057.
LTBC	2.903	2.903	2.903	2.903	2.903	2.903	2.903	2.903	2.903	1950.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.247	2.141-	2.141-	2.247	2.247	2.247	2.247	2.247	2.141-	[illegible]
NILA	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	1931.
KOEB	1.615-	1.615-	1.615-	1.615-	1.615-	1.615-	1.615-	1.615-	1.615-	1086.
HVVK	0.503+	0.000-	0.251	0.303	0.508+	0.000-	0.000-	0.000-	0.000-	97.
DRAK	0.000-	0.000-	0.000-	0.000-	0.458	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.378+	0.000-	0.378+	0.000-	0.000-	0.000-	0.000-	0.000-	0.251	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SWAN	0.100+	0.040	0.079	0.000-	0.100+	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.539	0.000-	0.000-	0.000-	0.000-	0.098	0.567+	0.667+	0.667+	217.
PALM	0.378+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.252	0.378+	67.
SP RES RL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
#DEMAND	--- (GW) --- (=)									
	21.752	21.419	21.017	20.540	19.885	18.724	17.349	15.486	15.061	12362.

#	PERIOD 10									(GWH)
# STN OUTP	--- (GW) --- (+)									
# ARNT	1.610	1.610	1.610	1.610	1.610	1.610	1.610	1.610	0.589-	976.
# CAMD	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
# DUVA	2.815	2.815	2.815	2.815	2.815	2.815	2.815	2.815	2.815	1892.
# GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
# HEND	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	751.
# KEND	0.723-	0.723-	0.723-	1.236	0.723-	0.723-	0.723-	0.723-	0.723-	539.
# KRIL	2.131	2.131	2.131	1.543	2.131	2.131	1.295	0.830-	0.830-	1014.
# LTBO	2.998	2.998	2.998	2.998	2.998	2.998	2.998	2.876	1.221	1817.
# MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
# MATI	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	1639.
# MTLA	2.403	2.403	2.403	2.403	2.403	2.403	2.403	2.403	2.403	1614.
# SRNG	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
# TUTU	2.459	2.459	2.459	2.459	1.294	1.088-	1.088-	1.088-	2.459	1168.
# KOEB	1.720-	1.720-	1.720-	1.720-	1.720-	1.720-	1.720-	1.720-	1.720-	1156.
# HVVK	0.508+	0.504	0.508+	0.000-	0.508+	0.000-	0.000-	0.000-	0.000-	97.
# DRAK	0.667+	0.564	0.000-	0.000-	0.242	0.000-	0.000-	0.000-	0.000-	44.
# PALM	0.233	0.000-	0.169	0.378+	0.000-	0.000-	0.000-	0.000-	0.000-	50.
# GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
#										
# POWER IP	--- (GW) --- (+)									
# SNAM	0.100+	0.100+	0.100+	0.000-	0.067	0.000-	0.000-	0.000-	0.000-	16.
#										
# POWER EX	--- (GW) --- (-)									
# EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
#										
# PMP LOAD	--- (GW) --- (-)									
# DRAK	0.000-	0.000-	0.000-	0.000-	0.000-	0.132	0.667+	0.667+	0.667+	217.
# PALM	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.267	0.376+	67.
#										
# SP RES RL	--- (GW) --- (+)									
#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
#										
# $DEMAND	--- (GW) --- (=)									
#	21.624	21.284	20.893	20.419	19.768	18.614	17.247	16.389	14.972	12289.

APPENDIX

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	PERIOD 09									(GWH)
STM OUTP	--- (GW) --- (+)									
ARNT	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1096.
CAMO	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVA	2.917	2.917	2.917	2.891	2.917	2.917	2.917	2.917	2.917	1957.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEND	1.457	1.457	1.457	1.457	1.457	1.457	1.457	1.457	1.457	979.
KEND	1.191	1.963	1.038	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	546.
KRIL	2.276	2.276	2.276	2.276	2.276	2.276	0.830-	0.830-	0.830-	1078.
LTBO	2.112	2.112	2.112	2.112	2.112	2.112	2.112	1.082-	2.112	1312.
MAJU	[illegible].000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	[illegible].914	2.697	2.914	2.914	2.914	2.141-	2.141-	2.141-	2.141-	1661.
MTLA	[illegible].844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	1.026-	1722.
SRNG	0.206+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	1.
TUTU	2.075	2.075	2.075	2.075	1.088-	2.075	2.004	2.075	1.156	1197.
KOEB	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1167.
HVVK	0.476	0.508+	0.508+	0.000-	0.503+	0.000-	0.000-	0.000-	0.000-	97.
DRAK	0.667+	0.000-	0.000-	0.397	0.000-	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.378+	0.378+	0.378+	0.135	0.000-	0.000-	0.000-	0.000-	0.000-	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SWAW	0.000-	0.013	0.100+	0.000-	0.100+	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.000-	0.000-	0.000-	0.000-	0.000-	0.132	0.667+	0.667+	0.667+	217.
PALM	0.000-	0.114	0.000-	0.000-	0.000-	0.378+	0.000-	0.378+	0.000-	67.
SP RES RL&	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
SODEMAND	--- (GW) --- (=)									
	22.881	22.492	21.986	21.192	20.307	19.403	17.728	16.392	15.062	12541.

#	PERIOD 08									(GWH)
SIM OUTP	--- (GW) --- (+)									
ARWT	1.621	1.621	1.621	1.621	1.621	1.621	1.621	1.621	1.621	1089.
CAMD	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVA	2.917	2.917	2.917	2.917	2.917	2.917	2.917	2.917	2.917	1960.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEND	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	751.
KEND	1.033	1.033	1.033	0.723-	1.033	0.723-	0.723-	0.723-	0.723-	545.
KRIL	2.267	2.267	2.267	2.267	2.267	2.267	2.267	0.830-	0.830-	1224.
LYBO	2.062	2.062	2.062	2.062	2.062	2.062	2.062	2.062	1.082-	1284.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.574	2.489	2.444	2.574	2.574	2.574	2.141-	2.141-	2.141-	1584.
MTLA	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	1.026-	1722.
SRMG	0.198	0.000-	0.206+	0.206+	0.000-	0.000-	0.000-	0.000-	0.000-	35.
TUTU	3.016	3.016	3.016	3.016	1.996	1.088-	1.088-	1.447	3.016	1442.
KOEB	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1167.
HVVK	0.508+	0.508+	0.508+	0.000-	0.279	0.341	0.000-	0.000-	0.000-	97.
DRAK	0.667+	0.667+	0.332	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.378+	0.269	0.000-	0.154	0.000-	0.378+	0.000-	0.000-	0.000-	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SWAW	0.100+	0.100+	0.033	0.100+	0.000-	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.000-	0.000-	0.000-	0.000-	0.000-	0.132	0.667+	0.667+	0.667+	217.
PALM	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.267	0.378+	67.
SP RES RL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
#DEMAND	--- (GW) --- (=)									
	23.037	22.646	22.137	21.337	20.446	19.536	17.849	16.504	15.765	12727.

#	PERIOD 07									(GWH)
STN OUTP	--- (GW) --- (+)									
ARNT	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1096.
CAMD	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVR	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	1348.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEND	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	751.
KEND	1.567	1.567	1.567	1.533	1.567	0.723-	0.723-	0.723-	0.723-	711.
KRIL	2.257	2.257	2.257	2.257	2.257	2.257	0.830-	0.830-	0.830-	1071.
LTBO	2.998	2.998	2.998	2.998	2.998	2.998	2.998	2.998	1.082-	1815.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.332	2.141-	2.141-	2.141-	2.332	2.141-	2.141-	2.141-	2.141-	1458.
MTLA	2.844	2.844	2.844	2.844	2.844	2.318	2.844	2.844	2.032	1793.
SRNG	0.206+	0.000-	0.206+	0.206+	0.000-	0.000-	0.000-	0.000-	0.000-	35.
TUTU	3.015	3.015	3.015	3.015	1.666	3.015	2.741	1.754	3.015	1737.
KOSB	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1167.
HVVK	0.508+	0.508+	0.508+	0.000-	0.507	0.000-	0.000-	0.000-	0.000-	97.
DRAK	0.667+	0.667+	0.332	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.378+	0.378+	0.000-	0.353	0.000-	0.000-	0.000-	0.000-	0.000-	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SWAN	0.100+	0.100+	0.090	0.000-	0.073	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.000-	0.000-	0.000-	0.000-	0.000-	0.132	0.667+	0.667+	0.667+	217.
PALM	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.378+	0.267	67.
SP RES RL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
#DEMAND	--- (GW) --- (=)									
	23.362	22.965	22.449	21.638	20.734	19.811	18.101	16.737	15.379	12907.

#		PERIOD 06									#	(GWH)	#
# STM OUTP	# --- (GW) --- (+)												#
# ASNT	#	1.631	1.621	1.631	1.631	1.631	1.631	1.631	1.631	1.631	#	1096.	#
# CAMD	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# DOVE	#	2.637	2.637	2.637	2.637	2.637	2.637	2.637	2.621	2.637	#	1771.	#
# GRTV	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# HEND	#	1.118	1.118	1.118	1.118	1.118	1.118	1.128	1.118	1.118	#	751.	#
# KEND	#	1.191	1.963	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	#	527.	#
# KRIL	#	2.276	2.276	2.276	2.276	2.276	0.995	2.276	0.830-	0.830-	#	1147.	#
# LTBO	#	2.062	2.062	2.062	2.062	2.062	2.062	2.062	2.062	1.082-	#	1284.	#
# MAJU	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
# MATI	#	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	#	1439.	#
# MTLA	#	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	#	1911.	#
# SRWG	#	0.206+	0.000-	0.000-	0.065	0.000-	0.000-	0.000-	0.000-	0.000-	#	8.	#
# TUTU	#	3.016	3.016	3.016	3.016	2.881	3.016	1.088-	1.088-	1.086-	#	1412.	#
# KOEB	#	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	#	1167.	#
# HVVK	#	0.506+	0.377	0.508+	0.508+	0.000-	0.000-	0.000-	0.000-	0.000-	#	97.	#
# DRAK	#	0.667+	0.000-	0.667+	0.000-	0.000-	0.019	0.000-	0.000-	0.000-	#	14.	#
# PALM	#	0.378+	0.378+	0.378+	0.000-	0.000-	0.167	0.000-	0.000-	0.039	#	50.	#
# GTBS	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# POWER IP	# --- (GW) --- (+)												#
# SNAW	#	0.100+	0.000-	0.100+	0.092	0.000-	0.000-	0.000-	0.000-	0.000-	#	16.	#
#	#												#
# POWER EX	# --- (GW) --- (-)												#
# EXP1	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# PMP LOAD	# --- (GW) --- (-)												#
# DRAK	#	0.000-	0.050	0.000-	0.000-	0.071	0.000-	0.667+	0.667+	0.667+	#	217.	#
# PALM	#	0.000-	0.000-	0.206	0.000-	0.000-	0.000-	0.148	0.000-	0.378+	#	67.	#
#	#												#
# SP RES BL# --- (GW) --- (+)													#
#	#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.	#
#	#												#
# #DEMAND	# --- (GW) --- (=)												#
#	#	22.511	22.128	21.631	20.842	19.978	19.089	17.441	16.127	14.819	#	12436.	#

	PERIOD 05									(GWH)
STN OUTP	--- (GW) --- (+)									
ARNT	1.122	1.122	1.122	1.122	1.122	1.122	1.122	1.122	1.122	754.
CAND	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVA	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	1348.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEND	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.263	988.
KEND	1.239	1.794	0.982	0.723-	1.794	0.723-	0.723-	0.723-	0.723-	641.
KRIL	1.582	1.582	1.582	1.582	1.582	0.830-	0.830-	0.830-	0.830-	780.
LTBO	2.977	2.977	2.977	2.977	2.977	2.773	2.977	2.977	2.887	1978.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	1439.
MELA	2.317	2.317	2.317	2.317	2.317	2.317	2.317	2.317	1.026-	1423.
SRNG	0.206+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	1.
TUTU	3.016	3.009	3.016	3.016	2.930	3.016	2.234	1.088-	1.088-	1437.
KOEB	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1.737-	1167.
HVVK	0.508+	0.508+	0.508+	0.348	0.000-	0.194	0.000-	0.000-	0.000-	97.
DRAK	0.667+	0.039	0.667+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.378+	0.298	0.000-	0.378+	0.000-	0.000-	0.000-	0.000-	0.000-	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SWAW	0.100+	0.100+	0.100+	0.062	0.000-	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.000-	0.000-	0.000-	0.000-	0.000-	0.132	0.667+	0.667+	0.667+	217.
PALM	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.267	0.378+	0.000-	67.
SP RES RL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
$DEMAND	--- (GW) --- (=)									
	21.503	21.137	20.662	19.916	19.084	18.234	16.660	15.405	14.155	11879.

					PERIOD 04					(GWH)
STN OUTP	--- (GW) --- (+)									
ARNT	1.631	1.631	1.631	1.631	1.631	1.631	1.631	1.631	0.916	1022.
CAMD	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVA	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	1348.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEND	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1014.
KEND	0.723-	0.999	0.723-	0.723-	0.892	0.723-	0.723-	0.723-	0.723-	511.
KRIL	2.276	2.276	2.276	2.276	2.276	2.276	0.830-	1.350	0.830-	1133.
LTBO	2.345	2.345	2.111	2.345	2.345	2.345	2.345	2.345	2.345	1562.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	1439.
MTLA	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	1911.
SENG	0.206+	0.000-	0.000-	0.000-	0.206+	0.000-	0.000-	0.000-	0.000-	21.
TUTU	2.922	2.922	2.922	2.922	1.088-	1.088-	2.157	1.088-	1.088-	1209.
XOEB	0.868-	0.862-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	584.
HVVK	0.508+	0.508+	0.342	0.000-	0.508+	0.154	0.000-	0.000-	0.000-	97.
DRAK	0.667+	0.000-	0.000-	0.000-	0.430	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.378+	0.378+	0.378+	0.135	0.000-	0.000-	0.000-	0.000-	0.000-	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SNAW	0.000-	0.000-	0.100+	0.000-	0.038	0.100+	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXP1	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.479	0.204	0.000-	0.000-	0.000-	0.300-	0.667+	0.667+	0.667+	217.
PALM	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.267	0.378+	67.
SP RES RL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
#DEMAND	--- (GW) --- (=)									
	20.545	20.222	19.850	19.400	18.782	17.685	16.386	15.571	14.225	11676.

	PERIOD 03									(GWH)
STN OUTP	--- (GW) --- (+)									
ARNT	1.180	1.180	1.180	1.180	1.180	1.180	1.180	1.180	1.180	793.
CAMD	0 000-	0.000-	0.00C-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
DUVA	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	2.006	1348.
GRTV	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
HEND	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1.509	1014.
KEND	0.988	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	0.723-	487.
KRIL	1.582	1.582	1.582	1.582	1.582	0.830-	1.449	1.023	0.830-	865.
LTBO	2.998	2.998	2.422	2.853	2.998	2.998	2.998	2.998	2.998	1965.
MAJU	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
MATI	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	2.141-	1439.
MTLA	2.844	2.844	2.844	2.844	2.844	2.844	2.844	2.844	1.220	1742.
SRWC	0.206+	0.000-	0.000-	0.000-	0.000-	0.206+	0.000-	0.000-	0.000-	14.
TUTU	3.016	3.016	3.016	3.016	2.581	2.113	1.088-	1.088-	1.088-	1326.
KOEB	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	0.868-	584.
HVVK	0.508+	0.508+	0.508+	0.468	0.000-	0.000-	0.000-	0.000-	0.000-	97.
DRAK	0.667+	0.065	0.653	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	44.
PALM	0.000-	0.378+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.368	50.
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
POWER IP	--- (GW) --- (+)									
SWAW	0.100+	0.100+	0.100+	0.000-	0.067	0.000-	0.000-	0.000-	0.000-	16.
POWER EX	--- (GW) --- (-)									
EXPI	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
PMP LOAD	--- (GW) --- (-)									
DRAK	0.000-	0.000-	0.000-	0.081	0.000-	0.000-	0.667+	0.667+	0.667+	217.
PALM	0.378+	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.378+	0.253	67.
SP RES RL	--- (GW) --- (+)									
	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.
%DEMAND	--- (GW) --- (=)									
	20.234	19.916	19.550	19.107	18.498	17.417	16.138	15.335	14.010	11499.

# GENERATION COMMON EQUIPMENT COST (Rm)	#	0.000	#
# COLLIERY INSTALLATION COST (Rm)	#	0.000	#
# TRANSPORT CHANNEL INSTALLATION COST (Rm)	#	0.000	#
# RESOURCE INSTALLATION COST (Rm)	#	0.000	#

# OBJECTIVE FUNCTION CALCULATED (Rm)	#	5674.877	#
# OBJECTIVE FUNCTION SOLUTION (Rm)	#	5674.877	#

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

TABLE 9

OBJECTIVE FUNCTION

GENERATION COSTS

VARIABLE O&M COST (Rm)	1697.073
POWER IMPORT COST (Rm)	0.000
POWER EXPORT COST (Rm)	0.000
RELAXATION OF SPINNING RESERVE COST (Rm)	0.326

COAL COSTS

COLLIERY VARIABLE OUTPUT COST (Rm)	4057.096
COAL TRANSPORT CHANNEL COST (Rm)	0.000
STOCKPILE LEVEL COST (Rm)	-76.282
STOCKPILE INPUT COST (Rm)	[illegible].084
STOCKPILE OUTPUT COST (Rm)	5.286

RESOURCE COSTS

RESOURCE VARIABLE COST (Rm)	582.295

EXPANSION COSTS

GENERATION UNITS INSTALLATION COST (Rm)	0.000

			1	2	3	4	5	6		Total
#	#	# STK IN #	0.000	1.012	0.924	0.000	0.800	0.000	#	2.736 #
#	#	# STK OUT#	0.000	0.000	0.000	0.000	0.050	2.424	#	2.474 #
#	MATI#MATI	# STK LVL#	0.175	0.110	0.075	0.069	0.063	-8.895	#	-8.403 #
#	#	# STK IN #	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK OUT#	0.000	0.546	0.286	0.000	0.000	0.000	#	0.832 #
#	MTLA#MTLA	# STK LVL#	0.117	0.107	0.067	0.062	0.057	-8.404	#	-7.995 #
#	#	# STK IN #	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK OUT#	0.000	0.000	0.336	0.000	0.000	0.000	#	0.336 #
#	SRWG#SRVR	# STK LVL#	0.004	0.004	0.003	0.003	0.003	-0.246	#	-0.228 #
#	#	# STK IN #	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK OUT#	0.001	0.000	0.000	0.000	0.000	0.000	#	0.001 #
#	TUTU#TUT1	# STK LVL#	0.112	0.102	0.082	0.076	0.070	-7.669	#	-7.227 #
#	#	# STK IN #	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK OUT#	0.000	0.000	0.123	0.000	0.000	0.196	#	0.319 #
#	TUTU#TUT2	# STK LVL#	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK IN #	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK OUT#	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	SRWG#HILG	# STK LVL#	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK IN #	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #
#	#	# STK OUT#	0.058	0.000	0.000	0.000	0.000	0.000	#	0.058 #

# TOTAL COLLIERY VARIABLE OUTPUT COST (Rm) #	#	4057.096 #
# TOTAL TRANSPORT CHANNEL COST (Rm) #	#	0.000 #
# TOTAL STOCKPILE LEVEL COST (Rm) #	#	-70.282 #
# TOTAL STOCKPILE INPUT COST (Rm) #	#	3.084 #
# TOTAL STOCKPILE OUTPUT COST (Rm) #	#	5.286 #

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 8 === #

=== RESOURCE COST (Rm) === OVER STUDY PERIOD #

# STN # NAME#	YEAR 1	2	3	4	5	6		Total
# KOEB#	126.733	103.229	87.540	101.118	93.609	70.065	#	582.295 #
# GTBS#	0.000	0.000	0.000	0.000	0.000	0.000	#	0.000 #

# TOTAL RESOURCE OUTPUT COST (Rm) #	#	582.295 #

WILG	SENG	TRP CH	0.000	0.000	0.000	0.000	0.000	0.000	0.000

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 7.2

=== COAL STOCKPILES LEVEL/INPUT/OUTPUT[COSTS] (Rm) === OVER STUDY PERIOD

STA NAME	COL NAME		YEARS 1	2	3	4	5	6	
ARNT	ARNT	STK LVL	0.044	0.040	0.052	0.048	0.044	-4.243	-4.015
		STK IN	0.000	0.000	0.172	0.000	0.000	0.000	0.172
		STK OUT	0.000	0.000	0.000	0.000	0.000	0.133	0.133
CAMD	CAMD	STK LVL	0.098	0.090	0.082	0.076	0.063	-3.050	-2.641
		STK IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK OUT	0.000	0.000	0.000	0.000	0.076	0.345	0.421
DUVA	DUVA	STK LVL	0.089	0.081	0.074	0.069	0.063	-7.651	-7.276
		STK IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK OUT	0.000	0.000	0.000	0.000	0.000	0.123	0.123
GRTV	GRTV	STK LVL	0.031	0.028	0.026	0.024	0.022	-2.191	-2.060
		STK IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK OUT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEND	HEND	STK LVL	0.046	0.041	0.038	0.035	0.032	-3.898	-3.707
		STK IN	0.030	0.000	0.000	0.000	0.000	0.000	0.030
		STK OUT	0.000	0.014	0.000	0.000	0.000	0.003	0.017
KEND	KEN1	STK LVL	0.117	0.081	0.074	0.068	0.062	-7.958	-7.556
		STK IN	0.146	0.000	0.000	0.000	0.000	0.000	0.146
		STK OUT	0.000	0.285	0.000	0.000	0.000	0.000	0.285
KEND	KEN2	STK LVL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK OUT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KRIL	KRL1	STK LVL	0.083	0.076	0.070	0.064	0.059	-6.301	-5.950
		STK IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK OUT	0.000	0.000	0.000	0.000	0.000	0.125	0.125
KRIL	KRL2	STK LVL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK OUT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LTBO	LTBO	STK LVL	0.122	0.112	0.088	0.081	0.074	-8.219	-7.742
		STK IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		STK OUT	0.000	0.000	0.160	0.000	0.000	0.000	0.160
MAJU	MAJU	STK LVL	0.216	0.250	0.358	0.323	0.291	-6.953	-5.482

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCHENARIO D CASE 1) === KOPT-SD1
=== TABLE 7.1 ===
=== COST OF COAL MINED/TRANSPORTED (Rm) === OVER STUDY PERIOD #

# COL # NAME	# STA # NAME #	YEARS 1	2	3	4	5	6	#	#
# ARNT#	# OUTPUT #	56.676	46.492	42.654	39.132	35.908	2[illegible].933	# 247.787	#
# CAND#	# OUTPUT #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# DUVA#	# OUTPUT #	76.500	70.186	64.393	59.068	54.193	49.715	# 374.054	#
# GRTV#	# OUTPUT #	0.000	0.000	0.000	0.000	0.865	1.045	# 1.911	#
# HEND#	# OUTPUT #	32.940	30.222	27.726	25.434	23.334	21.408	# 161.064	#
# KEN1#	# OUTPUT #	50.826	47.505	74.618	68.452	62.805	57.615	# 361.821	#
# KEN2#	# OUTPUT #	0.000	0.000	35.783	33.763	39.726	36.446	# 145.718	#
# KRL1#	# OUTPUT #	47.515	43.589	39.994	36.693	33.663	30.882	# 232.336	#
# KRL2#	# OUTPUT #	0.000	15.089	13.844	12.701	11.653	10.690	# 63.976	#
# LTBO#	# OUTPUT #	103.118	94.606	86.789	79.622	73.045	67.027	# 504.207	#
# MAJU#	# OUTPUT #	20.144	25.411	23.313	21.388	19.622	18.002	# 127.880	#
# MATI#	# OUTPUT #	216.315	198.456	182.070	182.218	167.170	153.376	# 1093.604	#
# MILA#	# OUTPUT #	69.405	63.672	58.422	53.592	51.514	47.256	# 343.860	#
# SRVR#	# OUTPUT #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# TUT1#	# OUTPUT #	66.560	61.064	56.024	51.408	47.152	43.256	# 325.456	#
# TUT2#	# OUTPUT #	0.000	0.000	0.000	0.000	25.282	23.879	# 49.161	#
# KILO#	# OUTPUT #	2.179	3.793	3.480	3.192	2.929	2.687	# 18.259	#
# ARNT#ARNT	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# CAND#CAND	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# DUVA#DUVA	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# GRTV#GRTV	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# HEND#HEND	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# KEN1#KEND	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# KEN2#KEND	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# KRL1#KRIL	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# KRL2#KRIL	# TRP CH #	0.000	0.000	0.000	0.000	[illegible]	0.000	# 0.000	#
# LTBO#LTBO	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# MAJU#MAJU	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# MATI#MATI	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# MILA#MILA	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# SRVR#SRNG	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# TUT1#TUTU	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#
# TUT2#TUTU	# TRP CH #	0.000	0.000	0.000	0.000	0.000	0.000	# 0.000	#

```
----------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------
# ===  XOPT-SD1 (TEST-FX OPTIMISATION STUDY - SCENARIO D CASE 1)                ===   XOPT-SD1                   #
=== TABLE 6.4                                ===                                                              #
=== COST - SPINNING RESERVE RELAXATION (Pm) ===          YEAR 1993                                            #
# STA #=========================================== PERIODS ===========================================        #
# NAME#        11         12         13                                                                       #
----------------------------------------------------------------------------------------------------------------
#     #     0.000      0.000      0.000                                                          #     0.000 #
```

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)          ===  KOPT-SD1                         #
=== TABLE 6.2          ===                                                                                       #
=== COST - IMPORTS (Rm) ===                           YEAR 1993                                                  #
# STA #========================================= PERIODS ==============================================          #
# NAME#       11        12        13                                                                             #
-------------------------------------------------------------------------------------------------------------------
# SWAM#    0.000     0.000     0.000                                                           #      0.000      #
```

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)          ===  KOPT-SD1                         #
=== TABLE 6.3          ===                                                                                       #
=== INCOME - EXPORTS (Rm) ===                         YEAR 1993                                                  #
# STA #========================================= PERIODS ==============================================          #
# NAME#        1         2         3         4         5         6         7         8         9        10       #
-------------------------------------------------------------------------------------------------------------------
# EXP1#    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000       #
```

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)          ===  KOPT-SD1                         #
=== TABLE 6.3          ===                                                                                       #
=== INCOME - EXPORTS (Rm) ===                         YEAR 1993                                                  #
# STA #========================================= PERIODS ==============================================          #
# NAME#       11        12        13                                                                             #
-------------------------------------------------------------------------------------------------------------------
# EXP1#    0.000     0.000     0.000                                                           #      0.000      #
```

```
# ===  KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1)          ===  KOPT-SD1                         #
=== TABLE 6.4                           ===                                                                      #
=== COST - SPINNING RESERVE RELAXATION (Rm) ===       YEAR 1993                                                  #
# STA #========================================= PERIODS ==============================================          #
# NAME#        1         2         3         4         5         6         7         8         9        10       #
-------------------------------------------------------------------------------------------------------------------
#    #     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.00        #
```

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 6.1 ===

=== COST - STATION O&M (Rm) === YEAR 1993

STA NAMES	PERIODS 11	12	13	
ARNT	1.319	1.918	1.619	21.920
CAMD	0.000	0.000	0.000	0.000
DUVA	2.334	1.995	2.360	27.688
GRTV	0.000	0.000	0.000	0.000
HEND	1.622	2.056	2.190	24.789
KEND	0.611	0.602	0.539	7.858
KRIL	1.691	1.714	1.216	20.351
LTBO	2.458	2.539	2.284	28.435
MAJU	0.000	0.000	0.000	0.000
MATI	1.653	1.597	1.698	22.040
MTLA	2.331	1.485	1.950	26.128
SEWG	0.077	0.041	0.000	0.476
TUTU	1.330	1.952	1.283	21.361
KOEB	0.000	0.000	0.000	0.000
HVVA	0.083	0.083	0.083	1.076
DRAK	0.011	0.011	0.011	0.143
PALM	0.013	0.013	0.013	0.164
GTBS	0.000	0.000	0.000	0.000

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 6.2 ===

=== COST - IMPORTS (Rm) === YEAR 1993

STA NAMES	PERIODS 1	2	3	4	5	6	7	8	9	10
SWAN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 5 ===

=== RESOURCE USAGE (pu) === OVER STUDY PERIOD

RESOURCE NAME	YEARS 1	2	3	4	5	6	
KOEB	********	********	9672.885	********	********	********	56422.742
GTBS	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000

=== KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1

=== TABLE 6.1 ===

=== COST - STATION O&M (Rm) === YEAR 1993

STA NAME	PERIODS 1	2	3	4	5	6	7	8	9	10
ARNT	1.881	1.319	1.387	1.788	1.319	1.918	1.918	1.907	1.918	1.707
CAMD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DUVA	2.528	1.739	1.739	1.739	1.739	2.284	1.739	2.528	2.525	2.441
GRTV	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEND	1.622	2.181	2.190	2.190	2.135	1.622	1.622	1.622	2.115	1.622
KEND	0.539	0.562	0.561	0.567	0.711	0.585	0.790	0.605	0.606	0.599
KRIL	0.967	1.464	1.384	1.812	1.248	1.835	1.714	1.959	1.725	1.622
LTBO	2.215	2.539	2.476	1.968	2.492	1.617	2.287	1.617	1.653	2.290
MAJU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATI	1.810	2.078	1.597	1.597	1.597	1.597	1.618	1.758	1.943	1.597
MTLA	1.877	1.603	2.125	2.331	1.736	2.331	2.187	2.101	2.101	1.970
SRWG	0.000	0.003	0.044	0.065	0.003	0.024	0.109	0.108	0.003	0.000
TUTU	1.292	1.736	1.670	1.524	1.811	1.779	2.188	1.817	1.588	1.471
KOEB	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HVVK	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
DRAK	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
PALM	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
GTBS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	STK IN	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
	STK OUT	0.000-	0.000-	0.147	0.000-	0.000-	0.301	0.446
TUTU#TUT2	INITIAL							
	LEVEL	0.000						
TUTU#TUT2	STK LVL	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	
	STK IN	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
	STK OUT	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
SRWG#WLLG	INITIAL							
	LEVEL	0.058						
SRWG#WLLG	STK LVL	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	
	STK IN	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
	STK OUT	0.058	0.000-	0.000-	0.000-	0.000-	0.000-	0.058

# KEND#KEN2 #	STK LVL#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-			#
# # #	STK IN #	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000	#
# # #	STK OUT#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000	#
# KRIL#KRL1 #	INITIAL#									#
# # #	LEVEL #	0.904								#
# KRIL#KRL1 #	STK LVL#	0.904-	0.904	0.904	0.904	0.904	0.712-			#
# # #	STK IN #	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000	#
# # #	STK OUT#	0.000-	0.000-	0.000-	0.000-	0.000-	0.192	#	0.192	#
# KRIL#KRL2 #	INITIAL#									#
# # #	LEVEL #	0.000								#
# KRIL#KRL2 #	STK LVL#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-			#
# # #	STK IN #	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000	#
# # #	STK OUT#	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000	#
# LTBO#LTBO #	INITIAL#									#
# # #	LEVEL #	1.331								#
# LTBO#LTBO #	STK LVL#	1.331-	1.331	1.140-	1.140-	1.140-	1.140-			#
# # #	STK IN #	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000	#
# # #	STK OUT#	0.000-	0.000-	0.191	0.000-	0.000-	0.000-	#	0.191	#
# MAJU#MAJU #	INITIAL#									#
# # #	LEVEL #	1.550								#
# MAJU#MAJU #	STK LVL#	2.350	3.450	4.550	4.550	4.480	3.750-			#
# # #	STK IN #	0.800	1.100	1.100	0.000-	0.000-	0.000-	#	3.000	#
# # #	STK OUT#	0.000-	0.000-	0.000-	0.000-	0.070	3.730	#	3.800	#
# MATI#MATI #	INITIAL#									#
# # #	LEVEL #	1.904								#
# MATI#MATI #	STK LVL#	1.904	1.310	0.970-	0.970-	0.970-	0.970-			#
# # #	STK IN #	0.000-	0.000-	0.103-	0.000-	0.000-	0.000-	#	0.000	#
# # #	STK OUT#	0.000-	0.594	2.340	0.000-	0.000-	0.000-	#	0.934	#
# MTLA#MTLA #	INITIAL#									#
# # #	LEVEL #	1.270								#
# MTLA#MTLA #	STK LVL#	1.270	1.270	[illegible]	0.870-	0.870-	0.870-			#
# # #	STK IN #	0.000-	0.000-	[illegible]	0.000-	0.000-	0.000-	#	0.000	#
# # #	STK OUT#	0.000-	0.000-	0.400	0.000-	0.000-	0.000-	#	0.400	#
# SRVG#SRVR #	INITIAL#									#
# # #	LEVEL #	0.045								#
# SRVG#SRVR #	STK LVL#	0.044-	0.044-	0.044-	0.044-	0.044-	0.044-			#
# # #	STK IN #	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.000	#
# # #	STK OUT#	0.001	0.000-	0.000-	0.000-	0.000-	0.000-	#	0.081	#
# TUTU#TUT1 #	INITIAL#									#
# # #	LEVEL #	1.218								#
# TUTU#TUT1 #	STK LVL#	1.218	1.218	1.071	1.071	1.071	0.770-			#

\# === KOPT-SD1 (TEST-RX OPTIMISATION STUDY - SCENARIO D CASE 1) === KOPT-SD1 #

=== TABLE 4.2 === #

=== COAL STOCKPILES LEVEL/INPUT/OUTPUT(AMOUNTS) (MEGA TONS) === OVER STUDY PERIOD #

STA NAME	COL NAME		1	2	3	4	5	6	
ARNT	ARNT	INITIAL							
		LEVEL	0.473						
ARNT	ARNT	STK LVL	0.473-	0.473-	0.678	0.678	0.678	0.473-	
		STK IN	0.000-	0.000-	0.205	0.000-	0.000-	0.000-	
		STK OUT	0.000-	0.000-	0.000-	0.000-	0.000-	0.205	0.205
CAMD	CAMD	INITIAL							
		LEVEL	1.070						
CAMD	CAMD	STK LVL	1.070	1.070	1.070	1.070	0.963	0.432-	
		STK IN	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
		STK OUT	0.000-	0.000-	0.000-	0.000-	0.107	0.531	0.638
DUVA	DUVA	INITIAL							
		LEVEL	0.966						
DUVA	DUVA	STK LVL	0.966	0.966	0.966	0.966	0.966	0.776-	
		STK IN	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
		STK OUT	0.000-	0.000-	0.000-	0.000-	0.000-	0.190	0.190
GRTV	GRTV	INITIAL							
		LEVEL	0.336						
GRTV	GRTV	STK LVL	0.336-	0.336-	0.336-	0.336-	0.336-	0.336-	
		STK IN	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
		STK OUT	0.000-	0.000-	0.000-	0.000-	0.000-	0.000-	0.000
HEND	HEND	INITIAL							
		LEVEL	0.473						
HEND	HEND	STK LVL	0.503	0.488	0.488	0.488	0.488	0.483-	
		STK IN	0.030-	0.000-	[illegible]	0.000-	0.000-	0.000-	0.030
		STK OUT	0.000-	0.015-	[illegible]	0.000-	0.000-	0.005	0.020
KEND	KEN1	INITIAL							
		LEVEL	1.124						
KEND	KEN1	STK LVL	1.270	0.960-	0.960-	0.960-	0.960-	0.960-	
		STK IN	0.146	0.000-	0.000-	0.000-	0.000-	0.000-	0.146
		STK OUT	0.000-	0.310	0.000-	0.000-	0.000-	0.000-	0.310
KEND	KEN2	INITIAL							
		LEVEL	0.000						

4 General

The LP software MGG and SCICONIC are installed on a single node. In order to run the software, softlinks have to be set which point to the software. This is done with a <.:profile> file under a users home directory. Assistance will be given in this regard.

The ERROR that occurs most often is the following.

RAN: not found

It should again be stressed that UNIX is case sensitive and {RAN} should have been entered as {ran}.

The script file {ran} aborts when an error is detected with resulting error messages.

If the script is aborted and the operating system is still UNIX, there are two methods to get back to the AEGIS operating system, ie

a. Press the {CTRL} key and while holding it press {z}.

b. Type /com/sh and press the ENTER key.

The input required here is exactly the same as for the report tables to be produced and is therefore not discussed in detail.

Finally the matrix will be created, the LP-Solver will be run, the report writer will be run and the printouts will be made. If an error occurs at this stage error messages will be displayed and the program will be stopped. It looks as follows,

```
## STATUS ##  Matrix generator MG is running.

## STATUS ##  MG successful - matrix generated.

## STATUS ##  LP-solver SCICONIC is running.

## STATUS ##  SCICONIC successful - solution status is
              OPTIMAL.

ITERATIONS    OBJECTIVE        INFEASABILITIES        TIME
     0        12.100000      496.819860(    14)       0.52
    22        20.600000        0.000000(     0)       0.78

    SOLUTION IS OPTIMAL

## STATUS ##  Report Writer RW is running.

## STATUS ##  RW successful - report generated.

   ****************************************************
   *                                                  *
   *           GENERATION EXPANSION MODEL             *
   *                                                  *
   *              PRODUCTION PLANNING                 *
   *                                                  *
   *            24 Apr 1991, 10:47:12                 *
   *                                                  *
   *                  END OF RUN                      *
   *                                                  *
   ****************************************************

   $
```

ng-2p{RETURN}

```
* NEW
* STUDY NAME          : TEST NG-2P
```

Several files can be selected to be printed. The following options will allow the user to do this.

```
*************************************************
*                                               *
*                  PRINTOUTS                    *
*                                               *
*************************************************

 !! The files followed by [y] will be printed     : !!
 !! The files followed by [n] will not be printed : !!

 !! 1 - Shortened initial input file          [y]  !!
 !! 2 - Shortened expanded input file         [n]  !!
 !! 3 - MPS file                              [y]  !!
 !! 4 - Sciconic solution file                [y]  !!
 !! 5 - Report Output                         [y]  !!

 ** If you want to toggel between [y] and [n],     **
 ** Enter the number, or                           **
 ** Press ENTER to continue.                       **
```

Option 2 the Shortened expanded input file will default not to be printed.

1{Return}

```
 !! 1 - Shortened initial input file          [n]  !!
 !! 2 - Shortened expanded input file         [n]  !!
 !! 3 - MPS file                              [y]  !!
 !! 4 - Sciconic solution file                [y]  !!
 !! 5 - Report Output                         [y]  !!

 ** If you want to toggle between [y] and [n],     **
 ** Enter the number, or                           **
 ** Press ENTER to continue.                       **
```

All globals are resolved.

The next option concerns the actual study to be performed.

```
**************************************************
*                                                *
*                   STUDY NAME                   *
*                                                *
**************************************************

*  CURRENT
*  STUDY NAME       : TEST NG-2P

** Enter the FILE NAME that contains the new STUDY.  **
** or                                                **
** press ENTER to continue with the current STUDY.   **
```

The study name of the previous study is displayed. The new study can be performed with the same study file, or a new study file could be used. To use the current study file again, the user only needs to press the ENTER key. If however a new file should be used the complete file name should be typed and the ENTER key pressed. If the input file to be used is on a different directory than the working directory the full pathname should also be entered. If the file name entered is not found an error message indicating this fact will be displayed and the user will be given the opportunity to retry. If the file was found the following will be displayed. If only the ENTER key was pressed nothing will be displayed.

3 {Return}

```
|| 1 - Energy output        Table   1.1 - 1.4  [y]
|| 2 - Planned Outage       Table   2          [y]  ||
|| 3 - Generation Output    Table   3          [n]  ||
|| 4 - Coal Output          Table   4.1 - 4.2  [y]  ||
|| 5 - Resource Output      Table   5          [y]  ||
|| 6 - Generation Costs     Table   6.1 - 6.4  [y]  ||
|| 1 - Coal Costs           Table   7.1 - 7.2  [y]  ||
|| 8 - Resource Costs       Table   8          [y]  ||

** If you want to toggel between [y] or [n],       **
** Enter the number, or                            **
** Press ENTER to continue.                        **
```

If by mistake a table has been turned off, which should remain on, the number of the table and the ENTER key should be pressed and the flag should again indicate [y]. The system will not progress past this point until only the ENTER key is pressed as confirmation that the correct tables will be created.

If the maximum dimensions were changed by the user, the source will be recompiled displaying the following messages.

```
## STATUS ##  Running the yearly version of MGG.

## STATUS ##  Compiling the MG code.

All globals are resolved.

## Status ##  Compiling the RW code.
```

The next option concerns the tables produced by the report writer.

```
**************************************************
*                                                *
*       TABBLES PRODUCED BY THE REPORTWRITER     *
*                                                *
**************************************************

 || The tables followed by [y] will be produced    : ||
 || The tables followed by [n] will not be produced: ||

 || 1 - Energy output       Table   1.1 - 1.4   [y]
 || 2 - Planned Outage      Table   2           [y]   ||
 || 3 - Generation Output   Table   3           [y]   ||
 || 4 - Coal Output         Table   4.1 - 4.2   [y]   ||
 || 5 - Resource Output     Table   5           [y]   ||
 || 6 - Generation Costs    Table   6.1 - 6.4   [y]   ||
 || 1 - Coal Costs          Table   7.1 - 7.2   [y]   ||
 || 8 - Resource Costs      Table   8           [y]   ||

 ** If you want to toggle between [y] or [n],      **
 ** Enter the number, or                           **
 ** Press ENTER to conticue.                       **
```

By default all tables will be created. If however some of the tables are not equired they can be eliminated at this point. For example to prevent table 3 from being created press 3 and the ENTER key. The flag following 3 on the display will now be turned to [n].

```
** Enter the new value for YEARS.                              **

5{Return}

C THE MAXIMUM NUMBER OF : 1.  YEARS                 - 5
C                       : 2.  PERIODS               - 52
C                       : 3.  SLICES                - 9
C                       : 4.  POWER STATIONS        - 20
C                       : 5.  COLLIERIES            - 14
C                       : 6.  TRANSPORT LINKS       - 14
C                       : 7.  IMPORT ROUTES         - 2
C                       : 8.  EXPORT ROUTES         - 2
C                       : 9.  RESOURCES             - 2
C                       : 10. LDC CURVES            - 5
C                       : 11. WMC CURVES            - 5
```

Again the system will not progress past this point untill only the ENTER key is pressed, when the user is satisfied that the maximum dimensions being displayed are correct.

```
************************************************************
*                                                          *
*      MAXIMUM DIMENSIONS FOR THE CURRENT STUDY            *
*                                                          *
************************************************************

   ## STATUS ## Reading the MGG file.

C THE MAXIMUM NUMBER OF : 1.  YEARS             - 2
C                       : 2.  PERIODS           - 52
C                       : 3.  SLICES            - 9
C                       : 4.  POWER STATIONS    - 20
C                       : 5.  COLLIERIES        - 14
C                       : 6.  TRANSPORT LINKS   - 14
C                       : 7.  IMPORT ROUTES     - 2
C                       : 8.  EXPORT ROUTES     - 2
C                       : 9.  RESOURCES         - 2
C                       : 10. LDC CURVES        - 5
C                       : 11. WMC CURVES        - 5


   **  If you want to change some -                         **
   **  Enter the number, or                                 **
   **  press ENTER to continue.                             **
```

Only the users of Generation Head Office will have the option to change some of these dimensions. To change a specific dimension the user should enter a number from 1 to 11 and press the ENTER key.

If for example the maximum number of years which is 2, by default should be changed to 5, press 1 and the ENTER key. You will be prompted for the new value. To enter the new maximum as 5, press 5 and the ENTER key. The changes will be made and displayed again if any furthe changes are required or if the entered values were correct.

1{Return}

The first optioin available is to chose to run a YEARLY or a PERIOD version of NEWGEX.

```
**************************************************
*                                                *
*               PERIODS OR  YEARS                *
*                                                *
**************************************************
|| Two versions of NEWGEX exist.               ||

|| 1 - PERIOD version                           ||
|| 2 - YEAR   version                           ||

|| Decide wich version you would like to use,   ||
|| by ENTERING  either 1 or 2                   ||
```

The user should either press 1 or 2 and ENTER key to select which version of NEWGEX should be used. once the number has been entered, it will be displayed to the user for confirmation.

1{RETURN}

```
|| You have chosen the PERIOD version           ||
|| If you want to CONTINUE pres ENTER, else     ||

|| ENTER 2 to select the YEAR version.          ||
```

If the information is correct press the ENTER key, otherwise perss 1 and the ENTER key (for this instance) to change what you have chosen initially. The system will not progress past this point until only the ENTER key is pressed as confirmation to the choise that was made.

Following this the maximum dimensions for the study will be displayed.

3 Detailed Discussion Of The Input Required

A typical NEWGEX run will look as follows. The running procedure is discussed with comments given in italics.

The operating system is AEGIS.

$ env{Return}

Welcome to SR9.5 SYS5 DOMAIN MOTD!

Put your message here.

The operating system is UNIX.

ran{Return}

```
#     # ####### #           #   #####  ####### #   #
##    # #        #         #   #     # #        # #
# #   # #        #         #   #       #        # #
#  #  # #####     #   #   #   #   #### #####     #
#   # # #         #  # #  #    #     # #        # #
#    ## #          # # # #     #     # #        # #
#     # #######    ##   ##      #####  ####### #   #

****************************************************
*                                                  *
*            GENERATION EXPANSION MODEL            *
*                                                  *
*               PRODUCTION PLANNING                *
*                                                  *
*              24 Apr 1991, 10:44:16               *
*                                                  *
*                   START OF RUN                   *
*                                                  *
****************************************************
```

upgraded to [Apolo Domain/OS Version SR10.3] which is a UNIX operating System.

It should be noted that once the UNIX operating system is running, ALL further user inputs sould be given in lower case as UNIX is case sensitive.

After '<ran> is entered the system is interactive requiring the user to read what is displayer and to respond correctivelywhen requiredto do so.

The following options can be selected by the user when running the system.

a. Alterng the dimensions of the current model.
b. Selecting which part (tables) of the report to produce.
c. Selecting the input file to be used.
d. Selecting which printouts should be produced.

APPENDIX G

PRODUCTION PLANNING - OPERATING GUIDE

It must be noted that this chapter is taken directly from the PRODUCTION PLANNING - OPERATING GUIDE.

1 Aim

The aim of this section of this document is to tell one how to use the Newgex Production System ie

Running the system.

Detailed discussion of the input required.

General.

Problem solving.

2 Running The System

The system is fired by running two scripts.
A script is an ASCII (readable) file which contains system commands.

<env> - Start UNIX operating system.

<ran> - Start the Newgex System. {lowercase}

The <env> script would probably fall away once the operating system running on the Apollos have been

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5. PROBLEM SOLVING.

Contact person - Bertus van Schalkwyk

Telephone - 800 5545

STATUS ## RW successful - report generated.

Large studies will run for a number of hours and the fact that the system is busy (running) will be displayed, eg

STATUS ## LP-solver SCICONIC is running.

If users want to get an estimate of the size (ie the combined number of variables and constraints) of the study to be run, as there is a soft limit on the size, they can contact Bertus van Schalkwyk. There exists a Lotus 1-2-3 spreadsheet which can do this calculation.