South Africa has always been an energy driven economy, with the mining industry being the backbone of the economy, laying a solid foundation for the development of a firm electrical infrastructure. To provide for a power hungry economy, Eskom was formed in 1921 [1]. Currently Eskom has a total installed capacity of just less than 40,000 MW produced by 24 power plants dispersed throughout the country; of these, fossil fuel (coal) fired power plants are most used. “Eskom is among the five largest utilities, as well as being one of the lowest cost producers of electricity (dollar equivalent R/kWh), in the world. The utility generates and supplies more than half of the total electricity consumed on the African continent” [1].

Despite such a great record, Eskom is faced with a looming crisis, in that the rate at which the present demand for electricity is growing, is putting considerable strain on the supply capacity. So much so, that the demand for electricity will surpass Eskom’s installed peak load capacity by the year 2007 [2], [3] and base load capacity by 2010 [4]. This is further confirmed Eskom: “Eskom’s peaking capacity will be depleted by the year 2007, and base load capacity by 2010” [5].

As a measure of contingency and containment, the government is spending billions of Rands on bringing back three mothballed power plants, which were decommissioned in the 1980s. These include the Camden, Grootvlei and Komati power plants. The new capacity is expected to be connected to the grid between 2005 and 2014 [6].

On the demand side, Eskom has successfully introduced DSM as a tool to restrain the ever growing demand for electricity.

What is DSM?
The term demand side management (DSM) – and its concept – was coined by Clark Gellings in the early 1980s [7]. The concept of demand side management can be summarised as the planning and implementation of those utility activities designed to influence the customer to use electricity in ways that will produce desired changes in the utility’s load shape [7], [9] and [10]. DSM activities include [11] (as shown in Fig. 1):

- Peak clipping: reduction of peak demand
- Strategic conservation: direct influence on load shape to alter end usage
- Strategic load growth: initiated by the utility to increase sales
- Flexible reliability: incentive driven usage flexibility
- Valley filling: building load during off-peak periods (used in conjunction with peak clipping)
- Load shifting: strategic transfer of load from peak to off-peak periods

DSM in South Africa
For the South African scenario the two primary activities that are being implemented by Eskom DSM are: (1) energy efficiency or strategic conservation – specifically targeting base load capacity constraints, and (2) load control (an amalgamation of load shedding, valley filling and peak clipping strategies) – specifically targeting peak load capacity problems.

Eskom has set its “DSM targets” as “total load reduction of 4255 MW over 20 years (2025)” [12].

Another demand side activity Eskom is seriously perusing is DSB – Demand Side Bidding.

What is DSB?
“Demand side bidding (DSB) is the mechanism that encourages consumers to offer to undertake changes in their usual pattern of consumption in return for financial reward” [13].

“By rescheduling load or agreeing to load reductions, consumers help to maintain a balance between electricity supply and demand and to ensure quality and security of supply” [14]. DSB starts from the proposition that it would be worthwhile paying some customers to shed their electricity load; in other words it is a way to use voluntary non-essential load reduction to reduce electricity demand” [rather than producing more generation capacity] [15].

DSB in Eskom’s electricity markets
The Eskom electricity markets; where DSB participation takes place, is segregated into two main market segments; the Energy Market and the Reserve Market [4].

The energy market
The Energy Market caters for power capacity constraints predictable for the next day. In the Energy Market, DSB participants make bids for the next day and dedicate DSB load for single hour time slots for the next day.
The reserve market

In the Reserve Market the demand side participants are committed to make load instantly available at different times of notification, thus standing-by to shed load as reserve capacity. This is the fundamental difference between the energy and reserve markets – delivery of load shed: day-ahead vs. instantaneous. The reserve market is further sub-divided into three markets segments (as shown in Fig. 2):

The instantaneous reserve market

Given the notification, within an action period of 10 seconds the demand side participant is to shed load; and keep it off for at least 10 minutes.

This instantaneous reserve is ideally suited for system stability; that is when there is a sudden drop in supply levels; the demand levels can be instantly brought down to maintain stability.

Ten-minute reserve market

Here once given notice, the customer needs to shed load within 10 minutes and keep the load off for at least 2 hours.

Supplementary reserve market

At a notification, the demand side is to shed load within 2 hours, and keep the load off for a minimum of at most 24 hours.

The proposed approach: Technology assessment of DSM within the South African context

So far in this paper DSM and DSB have been described adequately; the approach that will be followed further, in assessing DSB, is proposed as follows:

- The present: an assessment of the current stance of DSM within the South African context will be gauged using the technology balance sheet.
- The past: here the technology roadmap will be developed to determine the timely evolution of DSM within the Eskom environment.
- The future: here using the scenarios approach, the potential future of DSB will be gauged.

The technology balance sheet

The technology balance sheet is a graphical representation of the inter-relationships, inter-dependence and reliance between; technology, processes, products and markets (as depicted in Fig. 3 below) [16].

The complete technology balance sheet may be segregated into three distinct matrices; the products-markets matrix; the products-processes matrix and the technologies-processes matrix.

Defining the markets

For the purpose of developing the balance sheet, for this paper, the markets will be defined as the four Eskom DSM market segments described previously (section IV): Energy Market, Instantaneous Reserve, 10-minute Reserve and Supplementary Reserve Markets.

Defining the products

From an analysis of the six DSM activities of Fig. 1, peak clipping and load shifting may be utilized in immediately shedding load for DSM participation. Flexible reliability may also be considered as a DSM product – where the user receives benefits for allowing reduced quality of supply. Strategic conservation looks at a complete load reduction over a longer time period (as compared to peak clipping and load shifting). Therefore these will be defined as the four DSM products.

Defining processes and technologies

The processes will be defined herein as those activities which allow DSM participation to take place within the above defined markets. These are: load scheduling, thermal load storage, load management, energy management and real-time load monitoring.

Technologies will be regarded as those tools, knowledge and people which will be utilised in producing the DSM products through the processes. These will include: communication technologies (wired and wireless), energy efficient technologies (HVAC and lighting), hardware and software and co-generation technologies.

Bringing it all together: the graphical representation

The culmination of the parameters defined above brings the final technology balance sheet to Fig. 4. The technology balance sheet should be read from the rows of the "Technologies" down to the column of the "Processes" to determine the utilization of each technology in the processes. Thereafter the rows of the "Processes" should be matched with the columns of the "Products", thus deciphering the relevance of each process with the products.

Thereafter, as the final step, the applicability of each "Product" in the "Markets" may be determined my corresponding the columns and rows of the products-markets matrix.

To enhance the visual appeal of the technology balance sheet, symbols are used to depict the degree of weightage; which is done in three phases: high, medium and low.

The technology roadmap

Technology roadmapping provides a structured means for exploring and communicating the relationships between evolving and developing markets, products and technologies over time [17].
The generic roadmap can be described as a time based chart, comprising a number of layers that typically include both commercial and technological perspectives [17]. “The roadmap enables the evolution of markets, products and technologies to be explored, together with the linkages and discontinuities between the various perspectives” [17].

Roadmap vs. balance sheet

The single, clear distinction between the balance sheet and the roadmap is in the “time” variable – the balance sheet is a snapshot at one particular time, showing the specific interrelations between the technologies, products, processes and markets at one particular instant in time.

On the other hand the technology roadmap shows the sequential time dependent development of the specific parameters. This provides the technologist with an insight into the timely developments and evolution of the various parameters associated with the specific technology.

Customising for the South African context

The scenario in which DSM and DSB were introduced in South Africa is drastically different from the western world. In the USA DSM was first introduced in the 1970s as a corrective measure of the Arab oil embargo, whereas in South Africa, DSM was introduced in the late 1990s as corrective measure for the continually constrained supply capacity of Eskom.

The most significant dates within the South African scenarios are; 2007 (expected peak load capacity shortage) and 2010 (expected base load capacity shortage). Therefore for the focus of the technology roadmap, the development shall be within a 20 year time frame; starting from 1990 – traversing through to 2010, thus leading up to the above two significant dates.

The significant South African Parameters

The following are the significant parameters, which for the purpose of developing the technology roadmap, consist of the technology products associated with DSB. These parameters are either directly related to DSB or have further evolved to form the crux of the concept of DSB [12], [4]:

- TOU (time-of-use) tariff: introduced in the early 1990s and is still successfully being implemented.
- Real-time pricing (RTP): introduced in 1996/7 and successfully implemented up till 2004.
- DSM load control: introduced in 2001 as a measure to contain the growing peak capacity shortage.
- DSB: introduced in the Eskom environment in 2003, and is successfully being implemented.

Drawing from the balance sheet

As was the case with the balance sheet; “real-time monitoring” using both IT and communication technologies is linked with the processes of “load management” and “process/production scheduling”. Co-generation technologies are also linked with the processes of “load management” and “process/production scheduling”. Here co-generation is considered as a technology – however, one might argue, co-generation is not a technology, but an incentive; based use of on-site generation technologies to save electricity costs.

For that the Author will argue that technology may be considered as a combination of knowledge, tools and people [18]. Therefore co-generation technologies involves applying the knowledge of varying electricity tariffs [with RTP, TOU tariff periods and DSB signals] and using the tools of on-site generation stations (obviously driven by people) one implements the processes of “load management” and “process/production scheduling”, which in turn contributes to DSM and DSB savings. Therefore co-generation should be considered as a technology within the scope of this dissertation.

This brings the technology roadmap to Fig. 6. The time dependent technology products and markets of the roadmap (shown on the right side) are of significance, wherein the timely evolution of the technology products (and their applicability in the markets) is depicted.

The technology forecast

“Most planners and futurists reject the idea that planning should be conducted against one single ‘most likely’ or ‘most wanted’ image of the future. Rather, sets of scenarios should be used in planning” [19].

“Scenarios neither predict the future, nor prevent the unexpected from happening” [20], [21]. Therefore in essence a scenario-logic approach looks at various possible outcomes that have a probability of occurrence.

Scenarios within the South African context

As can be deciphered from the discussion leading up to the technology assessment of DSB; there are two possible occurrences within the South African context: Eskom running short of supply capacity (peak or base-load); or the successful restoration of surplus supply capacity, thus avoiding possible capacity shortages. These three possible occurrences present three distinct scenarios, as shown in Table 1.

The approach that will be taken here will be to present each scenario and analyse how the present would conform to uncertain future. The present is represented in this paper by the technology balance sheet; therefore the investigation will look into how the balance sheet will be altered through the scenario. However, due to space constraints, only the products-markets matrix of the balance sheet will be shown herein (other matrices remain unchanged).

Scenario 1

Severe peak capacity shortage Eskom has given an official account of the January 2007 blackouts by stating that more than 8 generation stations were “experiencing technical problems”, and as a result there

<table>
<thead>
<tr>
<th>Event</th>
<th>Details</th>
</tr>
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<tbody>
<tr>
<td>Scenario 1</td>
<td>Severe peak capacity shortage</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>Severe base-load capacity shortage</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Successful restoration of surplus supply capacity</td>
</tr>
</tbody>
</table>

Table 1: The three scenarios considered.
was a capacity shortage. However, demand was also 1000 MW higher than predicted [22]. The projections of peak capacity shortage in 2007 have actually materialised.

Given that during January 2007 (summer season), the demand side has experienced blackouts (as a result of higher than expected demand), the likelihood of a severe peak capacity shortage will be ranked as a high.

This rating can be further substantiated considering that the annual, national peak demand is highest in the winter season (June - August), as compared to the summer season. More outages can be expected in the winter season to come.

Scenario 2 has seen drastic alterations to the TBS as compared to scenario 1. Despite this scenario 2 would be a greater threat to DSB as a technology product, this due to the fact that the shifted load would need to be recovered – this would invariably require capacity; which is the main constraint in scenario 2.

“Demand side bidding redistributes load, not reducing overall energy consumption, therefore, if the load recovery periods (which follow load reduction periods) are not considered, then DSB’s effectiveness is not authentic” [23].

Scenario 3

Scenario 3 considers the event where the three mothballed power plants are successfully put back into full operation, as well as other successful supply side initiative being implemented by 2010 so that the grid sustains sufficient supply capacity, thus nullifying the possibility of the first three scenarios even occurring.

The likelihood of such an event taking place will be considered as a low.

This can be further supported by [22]: “Eskom would remain in a tight supply position until the first 750-MW base-load capacity (begins) coming on-stream in 2010/11”.

Net effect on the technology balance sheet

Note that scenario 3 has produced the lowest applicable rating in the Energy and Supplementary Reserve Markets. Surplus capacity would mean there would be minimal need to participate in day-ahead demand-supply balancing activities. Thus the low ratings in the Energy and Supplementary Reserve Markets.

The rating of the remaining two reserve markets has been set-up in such a manner as to keep DSB as the complete backup reserve in case of a sudden unplanned power outage. Thus note the high applicability rating of load shifting and peak clipping in the instantaneous and 10-min Reserve Market.

In scenario 3, DSB has been converted to a full back-up reserve activity – where only in the condition where there is an unplanned power interruption will DSB be utilised.

Conclusion

As a technology product, DSB has evolved from RTP and DSM. DSB was introduced into the South African market in 2003, and is currently being utilised as a tool to mitigate peak capacity constraints. However, the recent blackouts in South Africa have increased pressure on the supply side to restrain the growing demand, whereby DSB participation would see a sharp rise.
The present status-quo is riddled with the advent of the uncertain future. This paper has selected 3 specific scenarios covering the possible future occurrences, whereby the high likelihood scenarios (1 & 2) pose the greatest threat to DSB. Considering the uncertain future, the author makes the following recommendations.

**Recommendations**

**Further segregate the energy market**

Market segmentation is proposed with the consideration of base-load capacity constraint. This segmentation would further allow tweaking
of specific DSB products to their precise requirements. From this refinement more manageable market and DSB product chunks will be created. The proposal is based on creating 2 sub-market segments, as the following:

• Predicted (day ahead) base-load capacity constraints market:
This market will allow for planned day ahead base load shortages to be matched with willing DSB participant load.

For example, if tomorrow, planned maintenance is scheduled at a base-load serving power plant; this would be an ideal instance where willing DSB participants may be called in to balance demand with lowered supply. For this Flexible Reliability or even Load Shifting would be ideal. Here the supply side can cycle load shedding between DSB participants for the duration of the planned maintenance. Once the power plant is back-online, the day’s market will close.

• Real-time DSB participation market:
This market segment allows for the unplanned situations to be catered for; whereby if there is a sudden base load reduction, then DSB participation may be called in.

The participants of this Energy Market would not the be the same as the Reserve Market participants, as firstly the situation would call for load shedding for a longer duration; which the Reserve Market participants do not do. Secondly these customers should be paid an extra availability fee – as the load disruptions would be unplanned.

Another difference between this Energy Market segment and the Reserve Market segments would be that participants here would be single load customers (for easier manageability), whereas in the Reserve Market – since the load interruption is required for a short period – the customers could also be small aggregated loads (which are managed more complicatedly).

Segmenting the Energy Market would allow for greater flexibility in approaching base load capacity constraint situations for both planned and unplanned scenarios.

Invest in the supply side rather than DSB
Base-load capacity constraints cannot be mitigated or deferred for too long using DSB. This is because whatever load is shifted needs to be reinstated, and having a limited supply, this situation could be disastrous.

Therefore the final and most important recommendation – through the evaluation of DSB within the South African scenario – is that more investments should be made on the supply side to bring back as much supply capacity as possible.

DSB can provide a short term solution to a short term problem, however for long term problems; DSB is not a viable solution.

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References


