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UTILITY REQUIREMENTS FOR HTGRs

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Abstract

Eskom, the state utility of South Africa, is currently evaluating the technical and economic feasibility of the helium cooled Pebble Bed Modular Reactor with a closed cycle gas turbine power conversion system for future power generating additions to its electric system. This paper provides an overview of the Eskom system including the needs of the utility for future generation capacity and the key performance requirements necessary for incorporation of this gas cooled reactor plant.

INTRODUCTION

Eskom, the South African state utility, is currently investigating the viability of HTGRs as part of its future generating mix. This paper explains the background to Eskom's investigation and key requirements for any possible HTGR program.

SOUTH AFRICA'S ELECTRICITY SUPPLY INDUSTRY

Eskom generates over 95% of the electricity in South Africa with peak sent out demand in 1996 of 27 967 MW. Over 90% of this capacity is represented by large coal-fired stations (mainly 6 units of 600-700MW per station) fed by dedicated low cost coal mines. Eskom's current cost of coal is approximately R33/ton (US$7.50). This has led to a very low average retail power cost of approximately two US cents per kWh. This low cost structure has been achieved by a successful construction program of these coal stations in the 1970s and 1980s. This program achieved low costs because of its scale, both in terms of the size of the stations and the number of units ordered.

The program, in fact, proved to be over optimistic due to a fall in load growth from 8%/y to 5%/y in the early 1980's and Eskom over built, achieving a 50% reserve margin in the late 1980s and early 1990s. This led to the mothballing of some of the older coal stations (4513MW) and the delaying of the last station of the construction series, Majuba, at 4117MW, by eight years. With the growth of demand since that time this excess has been reduced and the operating reserve margin (excluding mothballed stations) for the utility at the peak demand in 1996 was below 15%. The issue facing the utility is therefore whether the current growth in demand will continue and how, if it does, to construct power stations in line with our current cost structure. These issues relate to total installed capacity, lead time and cost. There are also other factors which are starting to impact the utility. They are as follows.

The South African industry is very heavily dependent on primary industry: this is reflected in the load profile. Most of the extensive deep mining operations and heavy industry (steel, ferrochrome, aluminium etc.) operate on a 24 hour basis. The domestic market has, historically, been quite small as the black population had very limited access to electrical supply. The result was that Eskom installed very limited load following plants. The only ones that are used operationally are the two pumped storage schemes (1400MW) and limited hydro (600MW). As the drive to electrify the black townships continues (300 000 connections a year by Eskom alone, plus 150 000 by other authorities) and the secondary manufacturing and service industry grows, the need for load following plant is growing significantly.

In the apartheid era the South African industry became very inwardly focused. As the majority of the economically active population, and therefore customers, are close to Johannesburg the industry tended to be based close to this area, and away from the coast (on average 1000km away). The heavy industrial electrical load was therefore in this area and this was good for Eskom as the country's large coal deposits are in the same area. It is of note that the only non-coal base load station is the nuclear station (Koeberg 1800MW) near Cape Town, which is some 1400km from the next station (Tutuka, a 4000MW coal fired station). As South Africa has opened itself up to the world market after the fall of apartheid the need to base export orientated industrial plant near the coast has become apparent. Recent examples include the Hillside Smelter in Richards Bay (850MW load) and the Saldanha Steel Mill near Cape Town (200MW). There are plans for several more such major plants. This concentration of load on the coast will place severe demands on the Eskom transmission system as well as increasing the problems of quality of supply.

UTILITY NEEDS

Given this scenario, what are the outline requirements for new capacity for Eskom? The present analysis would indicate the following priorities:-

Cost	The capital and operating cost must match (or improve on) that achieved by large (4000MW+) coal stations.
Lead Time	The lead time must be as short as possible to avoid the type of over-capacity Eskom experienced at the end of the 1980s.
Load Following	The station must be able to load follow to compensate for the limitations on Eskom's current capacity.
Availability	This must be as high as possible. Eskom's current target for existing stations is 90% (7% planned outage and 3% forced).
Location	The plant should be able to be located where the load is without impacting the overall costs.
Environment	It is vital that any new plant must be environmentally (and publicly) acceptable.
Fuel Diversity	Although not vital it would be valuable to increase Eskom's diversity of fuel supply (currently 92% coal).

KEY PERFORMANCE FOR PBMR

The HTGR Eskom is investigating is the Pebble Bed Modular Reactor, a HTGR based on German fuel design using a closed cycle gas turbine for power conversion. Each of the above requirements has been reflected in the performance targets set for plant. It is accepted that these targets are EXTREMELY ambitious, but it is believed that they are achievable.

Unit Size	As a reference the module size is intended to be 100MW electrical output (220MW thermal). This size is dictated by the limits of the German Modul style core (without internal structures). The size is also very appropriate for sites as it allows multiple modules to support a single city.
Cost	The target capital cost, including interest and owner's costs, is under $1000/kW, which is in line with the costs of a coal fired station. It is assumed that this cost will only be achieved under series construction conditions (10 or more modules). The fuel cost is aimed to be comparable with current fuel costs at Koeberg (Eskom's PWR), which is in line with past German studies. The O&M costs are difficult to determine but, given the inherent simplicity of the system, a target figure of R3-6/MWh is expected. This just below Eskom's best figures for current coal stations.
Construction Time	The construction time for the series construction is targeted at 24 months, with 36 months for the lead module.
Load Following	The current reference design is a 10% per minute ramp increase in power from 20% to 100% power. A 10% step of current power level inside 1 second (e.g. 40% to 44%) and any load reduction (up to 100% load rejection) without trip. The plant is intended to operate at any power level (0-100%) on a continuous basis. Plant efficiency should not materially change between 20% and 100%.
Availability	Eskom's current plant is achieving over 90% availability. The target for the PBMR is a single planned outage of 30 days every six years. The trip rate is intended to be 1 per 70 000 hours, which is in line with current best practice for power reactors.
Location	The restrictions on siting for a nuclear plant are principally defined by the emergency plan requirements. The target for the PBMR is to have no planning restrictions beyond 400 meters from the reactor. In terms of seismic design the reference design is currently being aimed at the existing Koeberg site (with an SSE defined as horizontal acceleration of 0.3g) but the requirement is to be able to meet 0.5g for future versions without significant cost impact.
Environment	The current criteria for normal off site releases are seen, from a technical point of view, to be adequate. It should be readily possible to meet current severe South African criterion (250 uSv/y) for

Environment (cont.)	effluent releases during normal operation. The other related technical issue is that of waste, both process waste and spent fuel. The current strategy is to limit the processes which generate waste and to provide adequate storage in the plant systems to store all the spent fuel generated during the operating lifetime of the plant and to provide storage facilities until final disposal.
Fuel Diversity	In Eskom's terms the use of nuclear fuel could be seen to be advantageous as it diversifies away from the present heavy reliance of coal.

The item missing from this discussion is public acceptance. It is possible to build a station which meets the technical (and licensing) requirements but which does not have public acceptance. In many ways this has been the "Achilles Heel" of the current generation of nuclear plant. Public concern is based on two perceived problems, disposal of waste and accidents. The waste problem needs to be addressed in a wider context than a single design but it is vital that it is seen to be resolvable. The issue of accidents also must be seen to have been solved. The classic question is "Can the nuclear plant have an accident which could affect the public?". The answer for all current generation is "Yes, but it is such a remote possibility that ....". The only part of this answer that is heard is the first word, the rest is only limited mitigation! To be acceptable the answer must be "No". There must be no physically credible event which can necessitate offsite action.

As can be seen, the current targets for the PBMR are based in the needs of the utility. They are seen as very tough but if they can be demonstrated to be achievable during the current phase of investigation, the way may be open for further work on the project.

ANNEX A - ESKOM STATISTICS

ESKOM Peak Demands(1986-1996)

1986	18 278 MW
1987	20 001 MW
1988	20 587 MW
1989	21 871 MW
1990	21 863 MW
1991	22 342 MW
1992	22 460 MW
1993	23 169 MW
1994	24 789 MW
1995	25 133 MW
1996	27 967 MW

ESKOM Installed Capacity (gross) - 1996

Coal	34 125MW
Gas Turbine (oil fired)	342MW
Hydro	600MW
Pumped Storage	1 400MW
Nuclear	1 930MW

This equates to a total sent out capacity of 36 563MW of which 4 531MW is in reserve storage

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