Synchronous delivery

To drive economic expansion, South Africa needs to add 1,000MW a year to its generating capacity. Abundant coal supplies help provide cheap electricity but utility Eskom also relies on synchronous generators. Jacob Kamhis reports.

According to Zandile Mjoli, senior general manager for resources and strategy at South African utility Eskom, two-thirds of Africa's 700 million people live in rural areas, and less than 10 per cent of the rural population has access to electricity.

Mjoli says that getting to 20 per cent electrification would require adding 5,000MW annually for the next 30 years, necessitating a US$650 billion investment over two decades. But it would pay off in economic growth. Each 1 per cent increase in available power will increase GDP by an estimated 2–3 per cent.

Expansion programme

One economic bright spot in the area has been the Republic of South Africa. Eskom has recently launched a long-term, multi-faceted capacity expansion programme to meet its own growing needs as well those of other nations in the region. But besides adding generation facilities, the programme also includes economically distributing that power from the regions where it is produced to prime consumption areas hundreds of miles away. This entails the use of generators as synchronous condensers to improve the power factor and allow for more efficient transmission over the long distance lines.

South Africa has long been the driving economic force in the continent. With a population of 44 million and a 2005 purchasing power parity GDP of $527.4bn, it enjoys a GDP per capita of $11,900.

Although it has just 6 per cent of the continent's population, armed with a stable government and established infrastructure, the country accounts for 18 per cent of the continent's GDP, 50 per cent of its power generation, 45 per cent of mineral production and 50 per cent of purchasing power. Further progress depends on increasing the capacity and delivering it where it is needed.

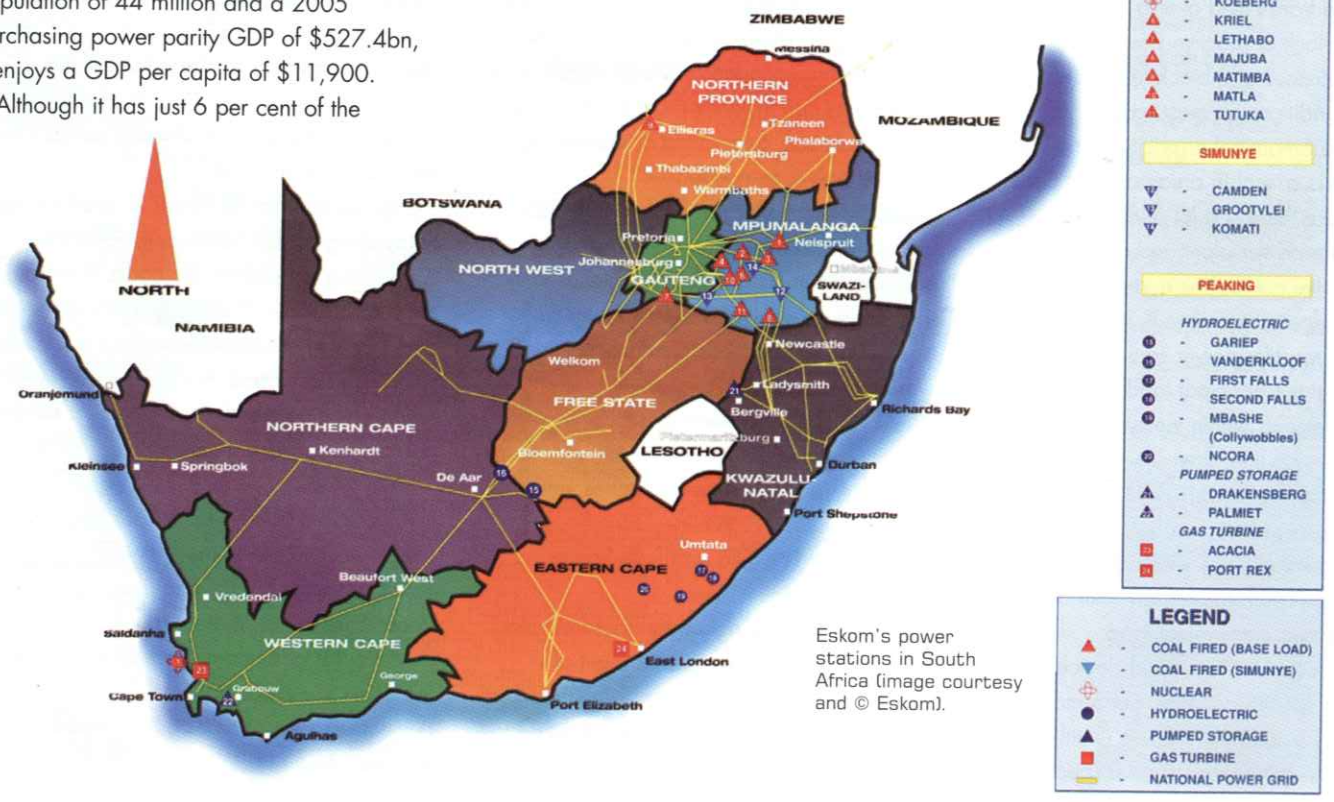
The law allows for independent power producers but nearly all of the country's electricity is generated by Eskom. Currently it has an installed capacity of 36,200MW, adequate to meet the current peak demand for electricity – 34,000MW. In fact, the country is a net exporter of electricity. But that situation won't last for long. To drive further economic expansion, the Ministry of Minerals forecasts a 1,000MW annual increase in domestic demand.

South Africa is a major coal producer with 5 per cent of the world's total reserves, and since it is a developing nation it isn't restricted in its CO_2 production by the Kyoto Accords. Accordingly, Eskom is reactivating three decommissioned coal-fired plant at Camden, Grootvlei and Komati at a cost of nearly $2 billion.

Two of the 8 x 200MW units at Camden were recommissioned in 2005. By the time all units at the three locations are back in action in 2010, they will add another 3,800MW to the grid. Eskom has also allocated another $9bn toward new generating capacity including natural gas, clean coal, pumped-storage hydro, wind and biomass. Future plans also include pebble bed reactors and solar concentration plant.

Coal dependence

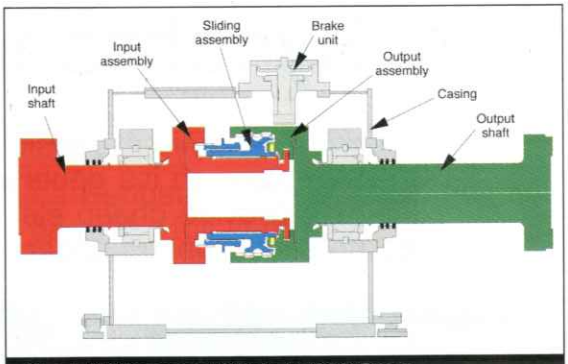
But for now, the country is still largely dependent upon coal. 71 per cent of the capacity consists of coal-fired plant and another 18 per cent from 2 shift coal. The remaining 11 per cent is a mix of nuclear (5 per cent) pumped storage (3 per cent) hydro (2 per cent) and gas (1 per cent). Since it is



Eskom's power stations in South Africa (image courtesy and © Eskom).

much cheaper to transmit electricity than the coal used to produce it, most of Eskom's large-scale plant are located in the north-eastern coal fields.

In fact, 14 of Eskom's 15 power stations with 500MW+ capacity are located in that region. The only other one is the 1,930MW Koeberg nuclear power plant located 1,500km away on the coast near Cape Town. The problem is that, although 34 per cent of the power demand lies along the coast, only 6 per cent of capacity is situated there. The coast is also where the largest demand growth exists.



Model 280T encased Clutch by SSS Gears.

Long distance delivery

Due to its abundant coal supplies, South Africa has some of the world's cheapest electricity, half the average cost of power in the US and one third that of some European countries. Consequently, coal has been and will remain a key part of the nation's energy strategy. Since this requires the use of long transmission lines from the coal producing regions to the coastal population centres, the country has used generators as synchronous condensers for the past four decades.

Reactive power is needed to provide voltage support and maintain system reliability. Consuming reactive power lowers the voltage and supplying it raises the voltage. It also increases transmission efficiency, boosting the amount of real power that can be transmitted over a line.

While a lack of reactive power can lead to voltage collapses and blackouts under extreme conditions, in most cases it just reduces the amount of capacity a line can carry. This is critical in areas such as South Africa where there is a lot of distance between the power plant and consumers. Since reactive power has a zero average voltage, it doesn't travel well, which means additional reactive power sources must be placed near the principal load.

Many elements within the system, including the transmission lines themselves, produce or consume reactive power. The key way to address imbalances is to use synchronous condensers – machines which are attached to the grid and synchronised to it, but are not connected to a mechanical load.

Several manufacturers build devices specifically for this purpose, but a more economical approach is to use unutilised or underutilised generators, such as peaking or retired units. Since synchronous condensers consume power from the grid to keep spinning, it is necessary to disconnect the turbine so energy is not wasted when using a generator.

One way to achieve this is by installing a self-synchronising clutch between the generator and the turbine. Almost all of those installed for this purpose in South Africa were manufactured by SSS Gears, UK. The turbine brings the generator up to speed, at which point it connects to the grid. Once it is synchronised, the turbine is shut down and the clutch disconnects it from the generator. The generator continues running, drawing power from the grid. Unlike other sources of reactive power such as condenser banks, synchronous condensers can instantly react to changing load conditions, generating or consuming reactive power as needed.

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According to Morgan L Hendry of SSS Gears, 19 South African generators were equipped with his company's clutches when they were originally installed so they could operate as synchronous condensers. The first were two clutch installations were retrofits – 15MW Rolls-Royce Avon gas turbines were retrofitted for steam turbines in Johannesburg back in 1966. Since then, clutches were installed on Pratt & Whitney Twin Pacs, Curtis Wright Mod Pod 50s and Rolls-Royce Olympus engines.

In addition to bringing the coal-fired plant back on line, two gas turbine plant are scheduled to come on line over the next three years. Eskom is building the first of these, to be located in the town of Atlantis, on the coast west of Cape Town near the Koeberg nuclear power plant. The other plant is being built next to the Petro facility at Mossel Bay, about midway between Cape Town and Port Elizabeth on the southern coast.

According to Clive Le Roux, Eskom's general manager for engineering, reliability rather than cutting edge technology was a key factor in selecting equipment for the plant. There are no major generator manufacturers in or near South Africa, so the units need to be simple, well-proven machines which can operate without extensive vendor support.

In June 2005, Eskom announced that it was purchasing seven V94.2A (now designated SSC5-3000E) units from Siemens in Germany, all to be equipped with SSS 280T clutches so they can operate as synchronous condensers. These are scheduled for delivery in August 2006 for commissioning the following year.

Finding Atlantis

Four of these will be installed at Atlantis, providing 588MW, and the other three at Mossel Bay where they will provide up to 440MW of peaking power, in addition to providing synchronous condensing for power coming from the base-load coal plant near Johannesburg. Initially the plant will run off jet fuel, but will switch to dual fuel once an LNG port is built in 2010.

Eskom took possession of the Atlantis and Mossel Bay properties in January 2006 and began construction for the arrival of the turbines in August, recruiting of personnel and building the transmission lines to connect the two stations to the grid.

Engineering firm PB Power is also looking at installing similar peaking/synchronous condensing units along the coast. According to Le Roux, South Africa has a fully developed ancillary services market for black start, spinning reserve and reactive power. The clutches will help both Eskom and PB Power participate in these markets.

With these gas turbines coming on line and the coal plant being recommissioned, South Africa will be able to meet its needs for the next few years. But beyond that, it will have to continue to add more capacity. There is potential for additional generation at some of the dams in the country, and Eskom is developing several types of renewable sources. IPG