Überblick zum Kraftwerksneubauprogramm von ESKOM in Südafrika

Eskom ist Südafrikas Haupstromversorger und ein Unternehmen im Eigentum des Südafrikanischen Staates. Eskom erzeugt rund 95 % des in Südafrika und rund 45 % des in Afrika insgesamt produzierten Stroms. Im Laufe der vergangenen Jahre hat die Reservekapazität an Kraftwerksleistung von Eskom stetig abgenommen, was zu Versorgungseinschränkungen mit partiellen Verbraucherabschaltungen geführt hat.

Ursachen waren im Wesentlichen zurückgehende Verfügbarkeiten beim bestehenden Kraftwerkspark sowie Versöhnungen bei der Inbetriebnahme neuer Kraftwerke. Daher hat Eskom ein Programm zur Optimierung und Erhöhung der Verfügbarkeit seiner Kraftwerke. Eskom ist ein Unternehmen im Eigentum des Südafrikanischen Staates. Eskom erzeugt rund 95 % des in Südafrika und rund 45 % des in Afrika insgesamt produzierten Stroms. Im Laufe der vergangenen Jahre hat die Reservekapazität an Kraftwerksleistung von Eskom stetig abgenommen, was zu Versorgungseinschränkungen mit partiellen Verbraucherabschaltungen geführt hat.

Eskom has embarked on a capital expansion programme and is currently building new power stations and major power lines to meet South Africa’s growing energy demand. Currently, Eskom owns and operates 27 power stations in South Africa with a total nominal capacity of 42,090 megawatt (electric). Eskom’s generating capacity comprises of 35,721 MWe, from coal-fired power stations, 1,860 MWe from nuclear power, 2,409 MW from gas turbines fuelled by diesel, 2,000 MW from pumped storage stations and 100 MW of wind turbines.

The company also maintains more than 359,337 kilometres (km) of power lines and substations with a cumulative capacity of 232,179 megavolt amperes (MVA). A further breakdown of the installed generating capacity is shown in Table 1.

### Eskom’s new build programme

In 2005, Eskom embarked on a capital expansion programme in order to support South Africa’s economic growth and increased energy requirements. Eskom is constructing new power stations that will provide an additional 11,132 MW of generation capacity (by 2021/22) in addition to the 6,137 MW of capacity that has been added to the system from 2005 to September 2013. Key projects currently in construction include Medupi, Kusile, Ingula and power delivery projects. These projects are at different stages of implementation. Eskom is also currently expanding its transmission grid throughout the country. A short overview of each of these projects is provided by Table 2.

### Overview of Eskom

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of stations</th>
<th>Number of units</th>
<th>Nominal capacity, MW</th>
<th>Percentage of total nominal capacity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired</td>
<td>13</td>
<td>87</td>
<td>35,721</td>
<td>85.1</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>6</td>
<td>16</td>
<td>600</td>
<td>1.4</td>
</tr>
<tr>
<td>Pumped storage</td>
<td>2</td>
<td>6</td>
<td>1,400</td>
<td>3.3</td>
</tr>
<tr>
<td>Nuclear</td>
<td>1</td>
<td>2</td>
<td>1,860</td>
<td>4.4</td>
</tr>
<tr>
<td>Gas</td>
<td>4</td>
<td>20</td>
<td>2,409</td>
<td>5.7</td>
</tr>
<tr>
<td>Wind</td>
<td>1</td>
<td>46</td>
<td>100</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Total nominal capacity:** 27, 124, 42,090, 100

### Table 1. Eskom installed generating capacity.

### Table 2. Overview of Eskom’s generation new build programme.

- **Table 2, figure 1:** Medupi power station project (6 × 800 MW)<sub>e</sub>
  - Contributing 800 MW<sub>e</sub> to the grid
  - Synchronisation of second unit expected in 2017

- **Table 2, figure 2:** Kusile power station project (6 × 800 MW)<sub>e</sub>
  - The project is making good progress
  - Synchronisation of 1<sup>st</sup> unit (unit 1) is expected at the end of the first half of 2017

- **Table 2, figure 3:** Ingula pumped storage scheme project (4 × 333 MW<sub>e</sub>)
  - Synchronisation of 1<sup>st</sup> unit (unit 3) is expected in the first half of 2016

- **Table 2, figure 4:** Sere wind farm project (46 × 2.2 MW<sub>e</sub>)
  - Successfully commercialised on time and on budget
  - Supplying up to 100 MW<sub>e</sub> into the grid based on wind conditions
Medupi and Kusile coal-fired power stations

Medupi and Kusile are the largest construction projects in the Southern Hemisphere and will be the 4th and 5th largest coal-fired power station complexes globally. These power stations will also be the largest dry-cooled stations in the world. The main packages of the boiler island (Mitsubishi Hitachi Power Systems), turbine (Alstom) and instrumentation and control (Alstom) where contracted as a fleet of 12 × 800 MW units. Table 3 provides a list of the main design specifications.

Causes for significant delays

The completion of Medupi and Kusile has been significantly delayed. The original commercial operation date for the first units of Medupi and Kusile were 2012 and 2013, respectively. Some of the major causes of these delays are listed below.

Infrastructure and skills development

Although not a direct cause of any delay, it should be noted that South Africa had not built any new coal-fired power stations for more than 20 years prior to awarding the Medupi and Kusile Power Station projects. The industry needed to rapidly expand to support the supply of 12 × 800 MW of coal-fired capacity. Local manufacturing capacity was expanded to support this; however, the availability of both local and international skills, in particular at supervisory level, was lacking. The period during which Medupi and Kusile Power Stations where contracted coincided with the expansion of local capacity in Germany and China, to support their build programmes, resulting in a global skill shortage at the time.

Front end engineering design

Due to the late decision given to Eskom to proceed with the new build programme, limited front end engineering design was performed prior to issuing long lead item specifications for the boiler and turbine islands. Design studies and integration continued through execution. This resulted in a greater number of design modifications and integration issues that contributed to schedule delays and compensation events. The early consequences of this was the lack of sufficient geotechnical data and issued related to the seismic design criteria. Boiler steel structures

The conversion of the steel structure basic design to a detailed design resulted in connections being incorrectly designed. This was only detected once installation had commenced. Structural members had to be modified on site and certain larger components needed to be returned to the workshop for modification. A total of more than 5,000 modifications were carried out on Medupi Unit 6, steelwork.

Use of incorrectly approved welding procedures

During post-production and in some cases during installation, it was discovered that certain welding procedures where incorrectly approved. These procedures needed to be re-approved using actual production parameters. Of the over 200 procedures requiring re-approval, 4 procedures on thick-walled components affecting X10CrMoVNb9-1 and 10CrMo9-10 material did not pass. This resulted in components already installed on Medupi unit 6 and Kusile unit 1 requiring in-situ repairs or additional post-weld heat treatment. Components fabricated for 5 units where affected. Components affected included P91 circular weld on headers, separator vessels (eventually all four replaced on Medupi unit 6) and the start-up vessel.

Post-weld heat treatment charts fraudulently produced

Heat treatment charts where produced without heat treatment or incorrect heat treatment. Over 9,000 welds which were potentially affected had to be verified to establish whether post-weld heat treatment (PWHT) was performed. This resulted in more than 400 welds with wall thickness ≤ 10 millimetres (mm) being cut out and replaced and more than 400 welds with wall thickness > 10 mm being heat-treated. Areas cut and re-welded included the inlet and outlet connecting tubes of super heater 3 and re-heater 2.

Databook approvals

During the review of databooks for final approval, it was discovered that there were additional welding procedures not appropriately qualified thus requiring re-qualification. Welder qualifications and re-testing documentation was missing and PWHT charts showed deviations from procedures. A significant amount of work had to be done post-fabrication and installation to close out the databooks prior to pressure test.

Installation of pressure parts

Insufficient control and measurement during the installation of the water walls resulted in the furnace dimensions being out of tolerance. This compromised the clearance between the heating element bundles and water walls. On Medupi unit 6, the re-heater 1 alignment at the outlet of the furnace was particularly bad with elements having reduced pitch between tubes, reduced expansion gaps between tubes and the water walls and a significant number of touching tubes. The re-heater outlet tubes where cut and re-welded to achieve the required tolerances. The interventions proposed for subsequent units have had a positive impact on the alignment of the re-heater tubes.

Distributed control system

Several critical defects where picked up during the first distributed control system (DCS) factory acceptance test. The Modifications consumed a considerable amount of time. The DCS was finally accepted for Medupi after 8 factory acceptance tests and several concessions being granted. There were more serious concerns relating to the boiler protection system, however, these issues could not be resolved ultimately leading to Eskom reissuing the design and supply of the boiler protection system to a separate contractor. Due to the poor performance of the contractor on Medupi the DCS and boiler protection system was re-contracted for Kusile Power Station.

Stikes and labour unrest affect product

Both Medupi and Kusile have been affected by labour unrest, however, this has been more prevalent on the Medupi site. Medupi has had numerous periods of labour unrest since commencement. Concerted efforts are being made to manage the relationship between Eskom, contractors and labour to prevent further delays as a result of labour unrest. It is estimated that labour unrest has caused more than a year’s delay at Medupi Power Station.

Medupi build status

Medupi is a greenfield coal-fired power plant project located west of Lephalale, Limpopo Province, South Africa. The name “Medupi” is a Sepedi word which means “rain that soaks parched lands, giving economic relief”. The power station will be the fourth largest coal-fired plant in the southern hemisphere, and will be the largest dry-cooled power station in the world. Medupi Unit 6 has added 794 MW, to the grid, with an-
other 3,970 MW, due to be commissioned by 2019. Once completed, Medupi will be the 5th largest coal-fired power station globally. Steady progress is being made to achieve the revised dates for commercial operation. There are day to day technical challenges that the contractors and Eskom are working through to ensure these revised dates are not compromised. Table 4 provides the revised commercial operating (CO) dates for the remainder of the 5 units. Medupi unit 5 will be the next unit to go commercial in the third quarter of 2017. The programme to achieve this is being tracked closely to mitigate any potential delays. The boilers have already been successfully pressure tested. Preparations for back energising are currently in progress, which will allow for additional commissioning activities to proceed. Figure 1 provides the dates for the key milestones to achieve commercial operation in 2017.

### Kusile build status

Kusile Power Station is located close to the existing Kendal power station, in the Nkangala district of Mpumalanga. Kusile will be Eskom’s first power station fitted with flue gas desulphurisation (FGD). Once completed, Kusile will be the 4th largest coal-fired power station in the world. The first unit of Kusile is expected to be in commercial operation by October 2017. Table 5 provides the revised commercial operating dates for the 6 units of the power station. Kusile Unit 1 is progressing well to achieve first synchronisation to the grid by the second quarter of 2017. The boiler hydro test has been completed. The replacement of the instrumentation and control contractor, at a late stage in the project, has placed the distributed control system installation and commissioning on the critical path. The first factory acceptance tests are ongoing. Other key milestones and dates to achieve first synchronisation are provided in Figure 2.

### Ingula pumped storage

The Ingula pumped-storage scheme, located within the Little Drakensberg mountain range, 23 km north-east of Van Reenen’s, comprises an upper dam (Bedford) and a lower dam (Braamhoek). The distance between the upper and lower reservoirs is 4.6 km, with an elevation difference of about 470 metres (m). The reservoirs are connected through underground waterways to an underground powerhouse complex, which will house four 333 MW pump turbines with a total capacity of 1,332 MW. The upper reservoir is concrete-faced rocks fill embankment dam, 41 m high, with a total capacity of 22.4 million cubic metres (m³) and an active water storage volume of 19.2 million m³. The 39 m high lower dam is a roller-compact concrete, with a total capacity of 26.3 million m³ and an active

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**Table 4. Medupi power station commercial operating dates.**

<table>
<thead>
<tr>
<th>CO Date</th>
<th>Unit</th>
<th>Capacity, MW</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2015</td>
<td>Unit 6</td>
<td>794</td>
<td>CO achieved 23 August 2015</td>
</tr>
<tr>
<td>September 2017</td>
<td>Unit 5</td>
<td>794</td>
<td>Progressing well, see additional detail on Unit 5 progress</td>
</tr>
<tr>
<td>December 2017</td>
<td>Unit 4</td>
<td>794</td>
<td>Progressing well</td>
</tr>
<tr>
<td>August 2018</td>
<td>Unit 3</td>
<td>794</td>
<td>Progressing well</td>
</tr>
<tr>
<td>February 2019</td>
<td>Unit 2</td>
<td>794</td>
<td>Progressing well</td>
</tr>
<tr>
<td>June 2019</td>
<td>Unit 1</td>
<td>794</td>
<td>Progressing well</td>
</tr>
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</table>

**Table 5. Kusile power station commercial operating dates.**

<table>
<thead>
<tr>
<th>CO Date</th>
<th>Unit</th>
<th>Capacity, MW</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2017</td>
<td>Unit 1</td>
<td>800</td>
<td>Progressing well, see additional detail on Unit 1 progress</td>
</tr>
<tr>
<td>November 2018</td>
<td>Unit 2</td>
<td>800</td>
<td>Progressing well</td>
</tr>
<tr>
<td>December 2019</td>
<td>Unit 3</td>
<td>800</td>
<td>Progressing well</td>
</tr>
<tr>
<td>July 2020</td>
<td>Unit 4</td>
<td>800</td>
<td>Progressing well</td>
</tr>
<tr>
<td>March 2021</td>
<td>Unit 5</td>
<td>800</td>
<td>Progressing well</td>
</tr>
<tr>
<td>December 2021</td>
<td>Unit 6</td>
<td>800</td>
<td>Progressing well</td>
</tr>
</tbody>
</table>
storage volume of 21.9 million m³. The scheme will be operated on a weekly cycle and will have an overall cycle efficiency of 78%. Eskom intends to synchronise unit 3 and 4 of this station in 2016. The synchronisation dates for all four units are provided in Table 6.

The operation of Ingula Power Station will greatly assist in alleviating some of the current supply constraints in South Africa, particularly during peak periods.

Current electricity supply situation

The environment in which Eskom operates today has significantly changed over the last 20 years. During the period when Eskom had large reserve margins there was a concerted drive to increase access to electricity as well as drive down real prices of electricity. Eskom achieved both of these goals. However this did result in a lack of investment into new generating assets as well as electricity tariffs not being reflective of what would be required to support renewed capital expansion/replacement.

Table 7 provides a time line of some of the defining periods in Eskom as it moved from oversupply to rotational load shedding.

Eskom has been managing a very tight system of supply and demand for several years and currently has little to no oper-

<table>
<thead>
<tr>
<th>Unit</th>
<th>First synchronisation</th>
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<tbody>
<tr>
<td>Unit 3</td>
<td>Q3 – 2016</td>
</tr>
<tr>
<td>Unit 4</td>
<td>Q4 – 2016</td>
</tr>
<tr>
<td>Unit 2</td>
<td>Q1 – 2017</td>
</tr>
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<td>Unit 1</td>
<td>Q1 – 2017</td>
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Table 6. Ingula dates.

<table>
<thead>
<tr>
<th>Eskom timeline 1994 to 2015</th>
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<tbody>
<tr>
<td>1994</td>
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<td>1995</td>
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<tr>
<td>1996</td>
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<td>2001</td>
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<td>2004</td>
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<tr>
<td>2006</td>
</tr>
<tr>
<td>2007</td>
</tr>
</tbody>
</table>
New Eskom power plants

Eskom was eventually unable to balance supply and demand necessitating rotational load shedding during June 2014, and more frequently from November 2014 to August 2015. The winter months are particularly risky due to the significant difference between base load and evening peak requirements. Figure 3 provides some key indices that illustrate deterioration in plant performance, the reserve margins typically available and the variance in load profiles between the summer and winter months.

Supplementary supplies from IPPs help to balance the supply and demand constraints. There is currently 1,795 MW of renewable energy IPPs (1,185 MW solar and 600 MW wind) supplying power to the grid at an average load factor of ±31%. A total of 5,817 MW is contracted with IPPs, consisting of 3,900 MW under the Department of Energy (DoE) REIPP programme and a further 1,356 MW dispatchable load is available under the demand response programme (supply agreements with industrial clients who are compensated to reduce load based on system constraints).

Along with the supplementary supplies, Eskom has implemented a targeted maintenance philosophy that will increase the levels of maintenance being performed within the constraints of the current supply and demand requirements. Two critical factors in stabilising the supply constraint and reducing the reliance on expensive generation options to meet demand is to ensure that:

- There is no further delays to the build programme and
- To improve the availability of the existing fleet.

Eskom is working on a strategy to improve availability from the current levels of 73 to 80% by financial year 2018/2019.

Figure 4 illustrates the criticality of improving the performance of the existing generation fleet. The performance improvement will have a direct influence on the duration required to reach a stable supply environment.

Although the electricity supply system remains highly constrained, the turnaround strategy implemented by Eskom has already started to show results. Eskom has not had to resort to load shedding since August 2015, with the exception of a short period for 2 hours 20 minutes. Current supply forecasts anticipate that there will be no further rotational load shedding till August 2016 and possibly beyond this date.

Overview of the South African build programme

Eskom acknowledges the country’s need for electricity generation capacity from the private sector in order to strengthen the system adequacy and meet growing power demand. Eskom purchases electricity from IPPs under various agreement schemes as well as from electricity generating facilities beyond the country’s borders. The Integrated Resource Plan (IRP), promulgated in 2011, by the DoE outlines the future of South Africa’s electricity expansion between the periods 2010 to 2030.

The development of the IRP took into account key constraints and risks such as:

- Reducing carbon emissions (limited to a cap of 274 million tonnes/year by 2025),
- New technology uncertainties,
- Water usage,
- Localisation and job creation,
- Southern African regional development and integration and
- Security of supply.

Excluding the committed new generation capacities (Medupi, Kusile, Ingula and Sere), the plan proposes an additional 9.6 gigawatt (GW) of nuclear, 6.3 GW of coal, 17.8 GW of renewables, 2.6 GW of hydro, 2.4 GW combined cycle gas turbines and
more expensive generation options to meet demand.

Although the electricity supply system remains highly constrained, the turnaround strategy implemented by Eskom has already started to show results. Eskom has not had to resort to load shedding since August 2015, with the exception of a short period for 2 hours 20 minutes. Current supply planning anticipates that there will be no further rotational load shedding till August 2016 and possibly beyond this date.

Conclusion

Eskom has experienced severe delays on its build programme. These delays have negatively impacted on the supply situation in South Africa. The delays have also had a consequential impact on the performance of the existing fleet due to the reduced opportunity to perform required planned maintenance.

The current supply constraints in South Africa will remain for the next few years. Eskom has implementing a turnaround strategy that will drive delivery on the new build projects and assist in improving the performance of the existing generation fleet. This coupled with the progress being made on the DoE IPP programmes will assist in the medium to long-term stability of the system and reduce the reliance on 3.9 GW open cycle gas turbines. A review of this plan conducted in 2013 has suggested that some of the capacity proposed in the plan could be deferred based on revised lower demand projections.

Allocation of capacities identified in the plan, for execution by IPPs or Eskom, are decided through a determination by the Minister of DoE (ministerial determination). Figure 5 shows the technology and capacities already released for “requests for proposals” through the ministerial determinations made in 2011, 2012 and 2015 on the current plan.

The allocation of projects to IPPs under the IRP is progressing well. Table 8 provides an update on the progress of the various programmes linked to securing the required capacities based on the ministerial determinations.

References

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