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Power generation

Power station pump selection: part 2

In this second of a two-part series, Willem van der Westhuizen and Tony Cattaert of South Africa's Eskom discuss the selection of the optimized pump configuration and drive option for the boiler feed pumps to be installed at the utility's newest power stations. These pumps are amongst the highest consumers of auxiliary electrical power within a power plant.

As part of a huge capital expenditure programme, South African electrical utility Eskom is building two new supercritical fossil fuel-fired power stations, namely Medupi and Kusile. With six units, each of a rated output of 794 MW and 798 MW, respectively, these power stations are currently in the design and construction phase. As discussed in the first article[1], the condensate extraction pumps and boiler feed pumps are amongst the highest consumers of auxiliary electrical power within a power station, and the selection of the correct optimized configurations and drive options for each of these pump types is therefore of great importance.

Following the discussion of the condensate extraction pumps in the first article, this second article focuses on the boiler feed pumps at the two new supercritical power stations. Two configuration options were considered, with the final choice based on the need to achieve high plant availability. In addition, four different variable speed drive options were available for selection, and the details of each option are included and discussed. The final decision in selecting the optimal drive option for the boiler feed pumps was based on an economic evaluation model that included three different modes of operation, initial capital cost and auxiliary power consumption based on the efficiency of the pump set over the expected life span of the power stations.

Boiler feed pump configuration

Two boiler feed pump (BFP) configurations were considered. The first comprised a single 100% duty, steam-turbine-driven BFP, with two 50% duty stand-by electrically driven BFPs complete with geared variable-speed fluid drive couplings (which is the Eskom standard configuration on wet-cooled condenser power stations). The second configuration involved three 50% duty, variable-speed electrically driven BFPs, two in parallel operation and one 50% on stand-by (the Eskom standard on dry-cooled power stations).

As for the condensate extraction pumps discussed in the first article, when comparing the two BFP configurations the following were considered:

- Initial capital costs
- Piping and instrumentation, including valves
- Electrical cabling and systems
- Space required for installation
- Redundancy
- Spares holding
- Effect of BFP turbine exhaust on cycle efficiency should a 100% duty, steam-turbine-driven BFP be installed on a dry-cooled station.

As determined by an economic evaluation using all the factors listed above, it was concluded that 3 x 50% duty variable-speed electrically driven BFPs would be the optimal configuration for the expected 50-year life span of the power stations.

BFP variable speed drives

The BFPs for the 3 x 50% duty electrically driven variable-speed pumps will consist of the following:

- A booster pump
- A main pump
- A variable speed drive (VSD) situated between the booster and the main pumps.

Note that the BFPs and drives considered will be sized and selected to satisfy the design point of the power station, which for the BFPs is the high-pressure (HP) turbine bypass operating point.

Pump VSD selection

Four alternative VSDs were considered, namely:

- High-speed VSD motor with speed reduction gearbox

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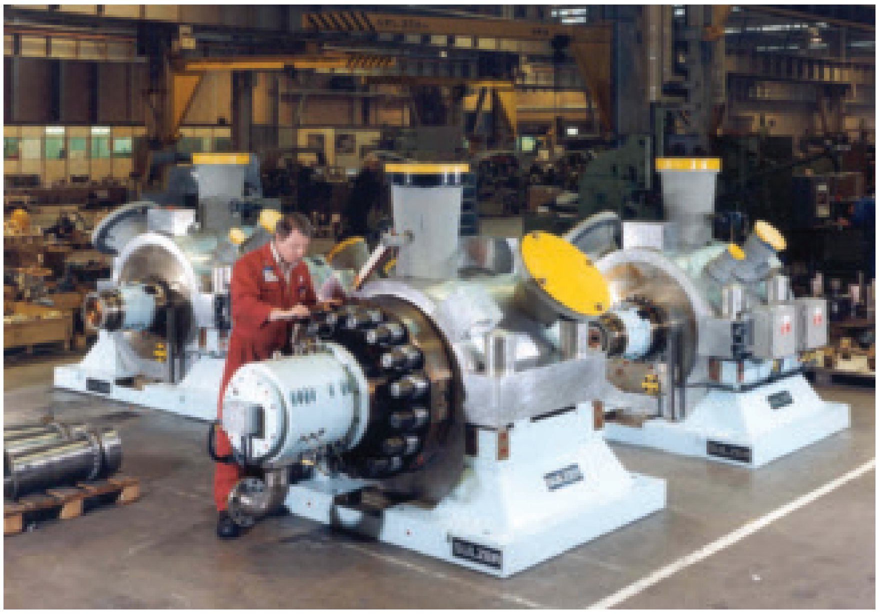
Figure 1. Newly built Sulzer boiler feed pumps.

- Low-speed VSD motor with speed increase gearbox
- Voith Vorecon variable-speed planetary gear fluid drive coupling
- Voith variable-speed fluid drive coupling.

BFP drive option 1

With this drive option a high-speed VSD electric motor is directly connected to the main pump. A speed reduction gearbox links the other side of the high-speed motor shaft to the booster pump, as shown in Figure 2.

This drive option would have the highest BFP set efficiency of 81.2% (pumps, motor and gearbox combined) with the lowest power consumption – 12.14 MW at the turbine maximum continuous rating (MCR) operating condition for one BFP set. Another advantage is that the BFP set would also run at very high efficiency and low power consumption at part-load conditions.

The biggest disadvantage would be the initial capital cost of the VSD and high-speed electric motor.

Eskom has experience of this BFP layout and drive option at its Matimba, Kendal and Majuba power stations. It is proven technology that contributes to high availability and reliability of the complete BFP train.

Drive option 2

With this drive option a low-speed VSD electric motor is directly connected to the booster pump. A speed increase gearbox links the other side of the low-speed motor shaft to the main pump (Figure 3).

This drive option would also have a high BFP set efficiency of 79.9% (pumps, motor and gearbox combined), with low power consumption (12.34 MW at turbine MCR operating conditions for one BFP set). The BFP set efficiency would not be as high as that for option 1 due to the speed increase gearbox losses (driving the main pump ~11.2 MW). The BFP set would again have the advantage of running at very high efficiency and low power consumption at part-load conditions.

As the capital cost of a low-speed variable speed electric motor is lower than that for its high-speed counterpart, option 2 would be more cost effective than option 1 but the cost is still high when compared to drive options 3 or 4.

Eskom has no experience with this drive option and the company would require access to reference plant and detailed technical information for this drive option before it would be seriously considered.

Drive option 3

The third BFP drive option utilizes an advanced fluid drive coupling – the Voith Vorecon variable-speed planetary gear fluid drive coupling (see Figure 4). In this option, the booster pump is connected

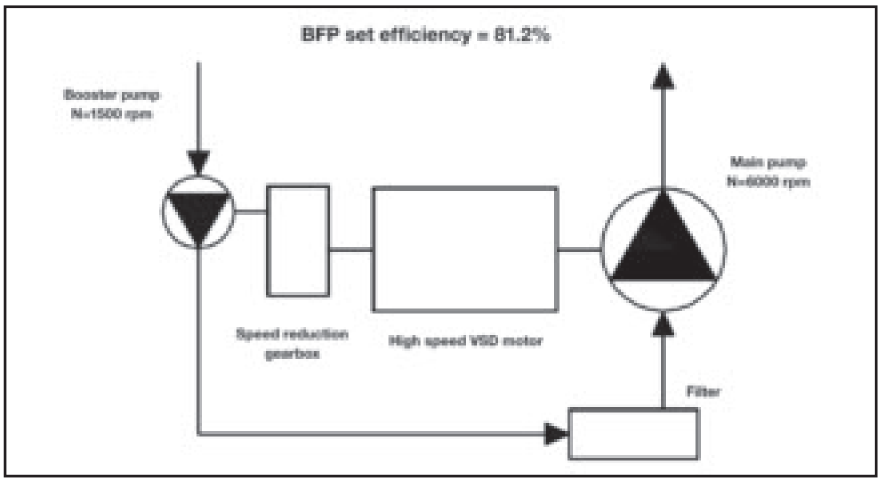

Figure 2. High-speed VSD electrically driven motor with a speed reduction gearbox.

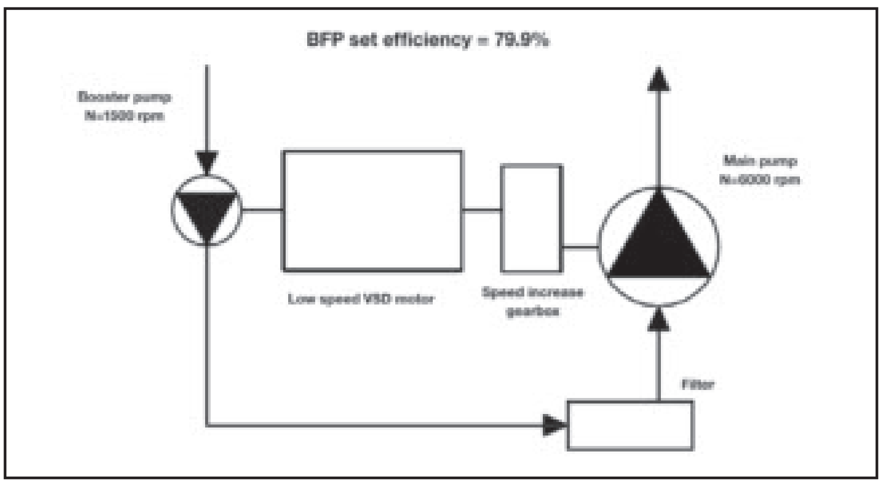

Figure 3. Low-speed VSD electrically driven motor with a speed increase gearbox.

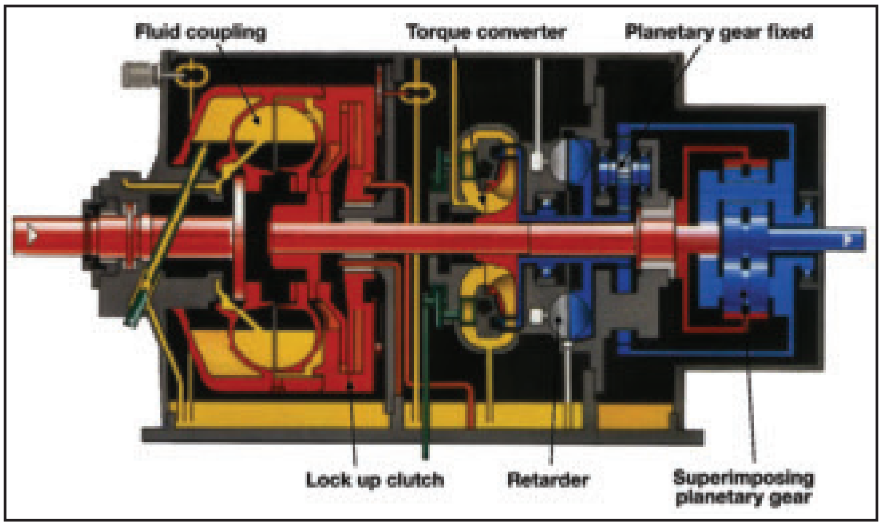

Figure 4. Cross-sectional diagram of the Voith Vorecon, Type RW.

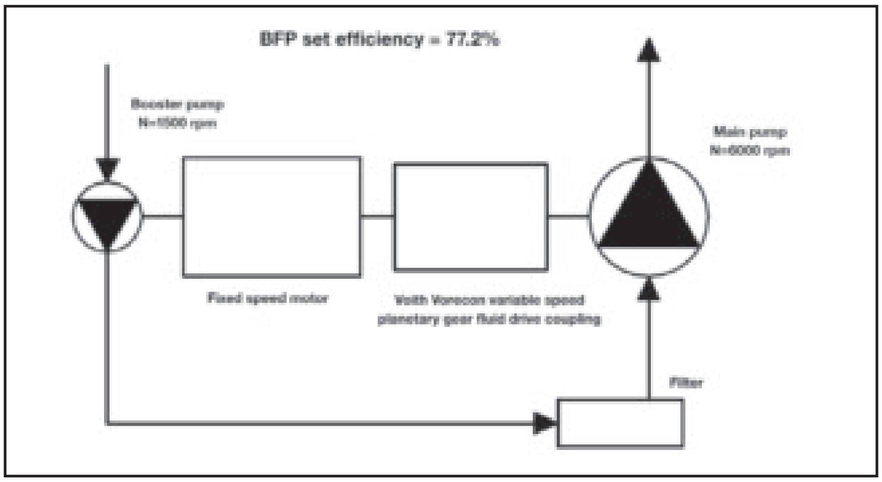

Figure 5. Fixed-speed electric motor with Voith Vorecon variable-speed planetary geared fluid drive coupling.

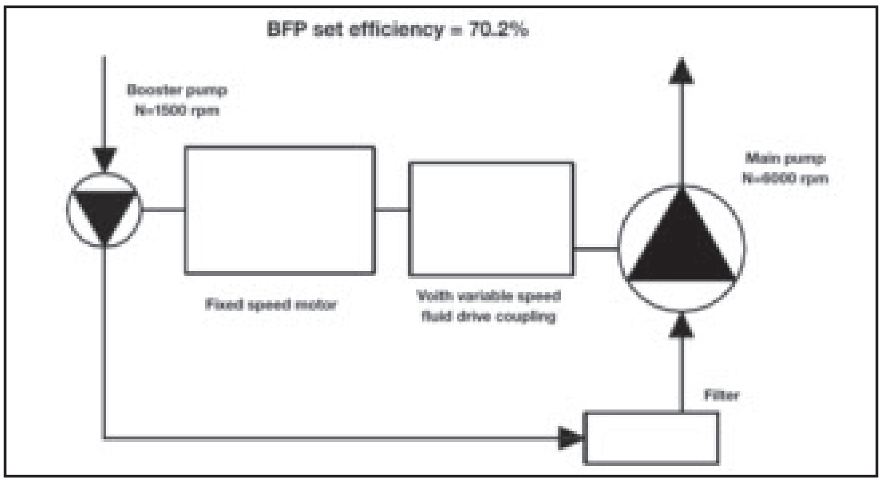

Figure 6. Fixed-speed electric motor with Voith variable-speed fluid drive coupling.

directly to a 19 MW, four-pole, double-shaft extension, 6.6 kV induction motor. The Voith Vorecon variable-speed planetary gear fluid drive coupling will connect the other end of the motor shaft to the main pump (Figure 5).

The main pump flow will be regulated by increasing or decreasing the speed of the Voith Vorecon unit.

This drive option would have a lower BFP set efficiency of 77.2% when compared to options 1 or 2. It would also absorb more power (12.76 MW, at turbine MCR operating conditions for one BFP set) than the first two options. However, although at part-load conditions the efficiency of the BFP set would be lower than options 1 or 2 it would be higher than for the fourth option[2].

This BFP drive option would also have a substantially lower capital cost than options 1 or 2, though still greater than option 4.

Eskom has no experience with the Voith Vorecon variable-speed planetary gear fluid drive coupling. A reference list was made available by Voith listing the installations where its Vorecon variable-speed planetary geared fluid drive couplings are in use. This list includes: BFPs, fans, compressors, coal mills and induced draught (ID) fans[3].

The two highest power rating Vorecons built and supplied for a BFP application are three 9.9 MW units installed in 2004 by Flowserve at Weston in the USA, and two 8.5 MW units installed in 1989 by Grosskraftwerk Mannheim in Germany.

In all areas of industry, the two highest power rating Vorecons built and supplied are: a single 28 MW unit installed in 2005 for a compressor drive test stand at Shenyang Blower Works, Shenyang, China; and a single 14.8 MW unit installed in 2004 for a compressor drive (BHEL, Lekhwair Gas Injection, Oman).

The 50% BFP unit considered for Medupi and Kusile will absorb about 12.34 MW at turbine MCR and 17.2 MW at run-out duty point.

BFP drive option 4

This BFP drive option utilizes a Voith variable-speed fluid drive coupling. In this option, the booster pump is connected directly to a 19 MW, four-pole, double-shaft extension, 6.6 kV induction motor. The Voith variable-speed fluid drive coupling connects the other end of the motor shaft to the main pump (Figure 6).

The main pump speed will be regulated by increasing or decreasing the speed of the Voith variable-speed fluid drive coupling.

This drive option will have the lowest BFP set efficiency of 70.2% compared to options 1, 2 and 3. It will also absorb more power (14.05 MW, at turbine MCR operating conditions for one BFP set) than the other three options. This fourth option has a further disadvantage when compared to option 3 – at part-load conditions the efficiency of the BFP set will be reduced due to the high slip losses in the fluid drive coupling.

This BFP drive option would have the lowest capital cost when compared to the other options considered. Eskom has experience with Voith variable-speed fluid drive couplings at its Matla, Duvha, Lethabo and Tutuka power stations. The BFPs equipped in this way at these power stations are only used for unit start-up and shutdown or are used as stand-by

Table 1. BFP drive option, efficiency, power absorbed and capital costs			
BFP drive option	**BFP set efficiency (%)**	**Power consumption (kW)**	**Capital cost (%)**
High-speed VSD electric motor with speed reduction gearbox	81.2	24274.8	203
Low-speed VSD electric motor with speed increase gearbox	79.9	24685.2	161
Fixed-speed motor with Voith Vorecon variable-speed planetary geared fluid drive coupling	77.2	25520.84	133
Fixed-speed motor with Voith variable-speed fluid	70.2	28103.1	100

BFPs in the case of unavailability of the 100% duty, steam-turbine-driven BFP.

Economic evaluation of drive options

Table 1 summarizes the BFP set efficiencies, power consumption using two 50% BFPs in parallel at the turbine MCR operating condition and the initial capital costs.

Although all four BFP drives were technically acceptable with emphasis on BFP set efficiency and power absorbed, the final decision was dependent on the economic evaluation results.

The new Eskom Generation economic evaluation model was used to calculate the overall cost per MWh (R/MWh) of the four drive options over the expected 50-year life span of the power stations. The economic evaluation considers three different modes of operation – base load, load following and two shifting – and includes:

- Initial capital costs
- Absorbed power
- Operating philosophy of power station
- Availability and reliability of plant
- Auxiliary power costs
- Maintenance costs.

The results from the economic evaluation model yielded the following order of preference:

1. Fixed-speed motor with Voith Vorecon variable-speed planetary gear fluid drive coupling
2. Low-speed VSD motor with speed increase gearbox
3. Fixed-speed motor with Voith variable-speed fluid drive coupling
4. High-speed VSD motor with speed reduction gearbox.

BFP drive recommendation

Based on the economic evaluation results, Eskom investigated further the fixed-speed motor with Voith Vorecon variable-speed planetary gear fluid drive coupling by visiting Mannheim power station in Germany and SES Meliti power station in Greece, both of which utilize Vorecon BFP drives. The visit was specifically aimed at gaining operational and maintenance experience from the two users[4]. The two Vorecons installed at Mannheim have been in service for more than 100 000 operating hours since installation.

Based on the high reliability and availability of the Voith Vorecons installed as BFP drives at the Mannheim and SES Meliti power stations, it can be concluded that this BFP drive option is viable and proven. The Voith Vorecon BFP drive is therefore the preferred option for the Medupi and Kusile power stations and should also be considered for future power stations.

Conclusion

It was therefore concluded and recommended that the Medupi and Kusile power station BFP configuration should remain as per the original specification; namely, 3 x 50% duty electric-motor-driven BFP sets in conjunction with a Voith Vorecon hydraulic drive coupling.

The final contract signed with Alstom for the 3 x 50% BFP sets per unit for the six units at the Medupi power station consists of the following equipment:

Sulzer booster pumps: HZB 303-720

Sulzer main pumps: HPT 350-370-6S/29

ABB electric motor: Squirrel cage induction motor DQWGH 1000/4-274

Voith Vorecon: RW16-145 F 9. ■

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