NEW APPROACH TO SHREDDER DRIVES DRIVEN BY ELECTRIC MOTORS

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Abstract

In the 1970s the sugar industry began moving away from steam turbine driven shredders in favour of electric motor drives. Due to the high inertias of the shredders, long starting times and high starting torque requirements, the preferred electric motor drives have been slip ring motors with liquid starters.

With the demand for higher Preparation Indices the shredder motor powers gradually increased. These ever-larger motors together with the power swings generally associated with shredders began to impact negatively on the sugar mill power houses and had the potential to cause loss of synchronism of the TAs and factory blackouts.

The accepted solution was to engineer an increase in the rotor resistance and thus motor slip in order to relieve the stress on the power supply of the large power swings. Increasing motor slip is easily carried out with slip ring motors and external wire wound resistances left in the rotor circuit during normal running. This solution has been the standard adopted in virtually all new southern African mills from then to the present day.

Pressure is being brought to bear by the large motor manufacturers in that slip ring motors and liquid starter applications are falling out of favour and being replaced with reliable, medium voltage, variable speed drives connected to robust, simple and low maintenance squirrel cage motors.

The sugar industry needs to keep up with this technology and take advantage of less expensive, more reliable shredder drive designs.

Keywords: sugarcane, factory process, shredders, shredder drives, electric motors

Introduction

In essence, this paper details the thinking that went into the new approach to electrical motor driven shredder drives where more cost effective and less maintenance intensive equipment could be used, and how additional benefits arose.

In the 1970s the sugar industry began moving away from steam turbine driven shredders in favour of electric motor drives due to demands for higher efficiencies and lower costs.

Due to the high inertias of the shredders, long starting times and high starting torque requirements, the preferred electric motor drives have been slip ring motors with liquid starters.

With the demand for higher Preparation Indices, shredder motor powers have gradually increased. These ever larger motors together with the power swings generally associated with shredders began to impact negatively on the sugar mill power houses and had the potential to cause loss of synchronisation of the TAs and factory blackouts.

This scenario came to a head in the mid-1980s at the new Felixton Mill which has two cane preparation lines, each with a 3000kW slip ring motor on the shredders. The frequency of power house blackout at Felixton became unacceptable and a solution had to be found.

The solution proposed by the late Theo Boshoff of Tongaat–Hulett Sugar Ltd (Boshoff, 1986, unpublished) was to smooth the load on the prime mover by making more use of the stored energy in the large rotating mass of the shredder rotor, i.e. using the flywheel effect, by allowing the shredder to slow down slightly on increasing load.

In order to accomplish this, the electric motor drive characteristics had to be made less ‘stiff’, and an additional external resistance was installed in the rotor circuit. Increasing the motor slip can easily be carried out on slip ring motors as they already have external starting resistance in the rotor circuit to provide the necessary high starting torque.

The starting resistance was shorted-out when the shredder reached full speed, while the additional resistance remained in circuit. In the Felixton case, this additional resistance effectively increased in the rotor resistance and thus motor slip (from 1% to ±2%). A smoothing effect on the power supply was immediately apparent. This solution has been the standard adopted in virtually all new southern African mills from then to the present day.

The TSB mills have an additional external resistance that creates a slip of 7%, resulting in an exceptionally smooth operation.

Generally all engineering designs and solutions are a compromise of good and bad and this solution is no exception. There are a number of significant disadvantages and some advantages associated with the use of slip ring motors.

Disadvantages

1. A slip ring motor is an expensive piece of equipment, two to three times the price of a normal induction motor of the same size. To that has to be added the price of the liquid starter, plus the additional dry resistor bank.

2. A shredder drive of 3500 kW and 7% slip results in an additional loss of 245 kW (Cotton, 1967). This loss is in the form of heat build-up in the resistor bank, which has to be dissipated.

3. An additional cost factor is the construction of a substantial housing for these resistor banks, which are large items of equipment. This building has to include a number of cooling fans to help dissipate the heat build-up mentioned above.

4. As well as being expensive, a slip ring motor is much more complex and thus less robust than a squirrel cage induction motor and, consequently, a higher degree of maintenance effort is required with increased costs.

5. Due to the size and cost of the slip ring motors, it is not normal practice to keep a spare motor. Should the motor fail, the shredder would thus need to be by-passed while repairs were under way. This period could cover a number of weeks.

6. The Preparation Index would then be reliant only on the knife set, and the consequent loss of extraction and revenue, particularly in diffusers, would be significant.

Advantages

A slip ring motor has two big advantages over normal squirrel cage motors:

1. The motor has a low current, high starting torque capability.

2. An additional external resistor can be installed in the rotor circuit to reduce the stiffness of the drive characteristics.

New approach

The latest technology was explored to see how it could be adapted to shredder drives. In addition, factors causing the shredder power swings were investigated to see if these could be mitigated. The purpose was to install less expensive, more robust shredder drives.

With regard to the first advantage of slip ring motors, i.e. starting of large electric motors:

- An increasing number of large squirrel cage induction motors are using MV AC variable speed drives for starting, as these drives are now equivalent to a slip ring motor in that VSDs can provide low current, high torque starting.

- The technology of MV AC variable speed drives has reached the point where this equipment is robust, reliable, self-diagnostic and has been designed in such a modular fashion that most maintenance involves replacing the faulty part in a plug-and-play scenario.

- Unfortunately this equipment is still extremely expensive and, depending on the manufacturer, it is at least the same or more costly than a slip ring motor solution.

With regard to the second advantage, i.e. reducing the stiffness of the drive:

- The stiffness of the drive characteristics refers to the ability of the motor to resist changes in speed and is related to the percentage slip for which the motor is designed.

- The rotor resistance and motor efficiency are determined by the slip.

- The motor industry generally strives for a high efficiency, i.e. low losses which require a low rotor resistance and result in a low percentage slip.

- In large motors the percentage slip is in the order of 1% and, for a 6-pole motor, nominally 1000 rpm, the full load slip speed will be 990 rpm.

- These motors have a very stiff characteristic.

Should the load induce a slowing down from 990 rpm, the motor would instantly demand a high current to produce torque to resist this reduction in speed.

This can be compared to an identical motor with 7% slip, where the full load slip speed is 930rpm (Figure 1). From the figure it can be seen that this motor is much more relaxed about a reduction in speed in that both the magnitude and rate of change of the additional current is considerably less.

It is thus important that the issue of power swings is taken into account and the effect on the power house mitigated as much as possible.

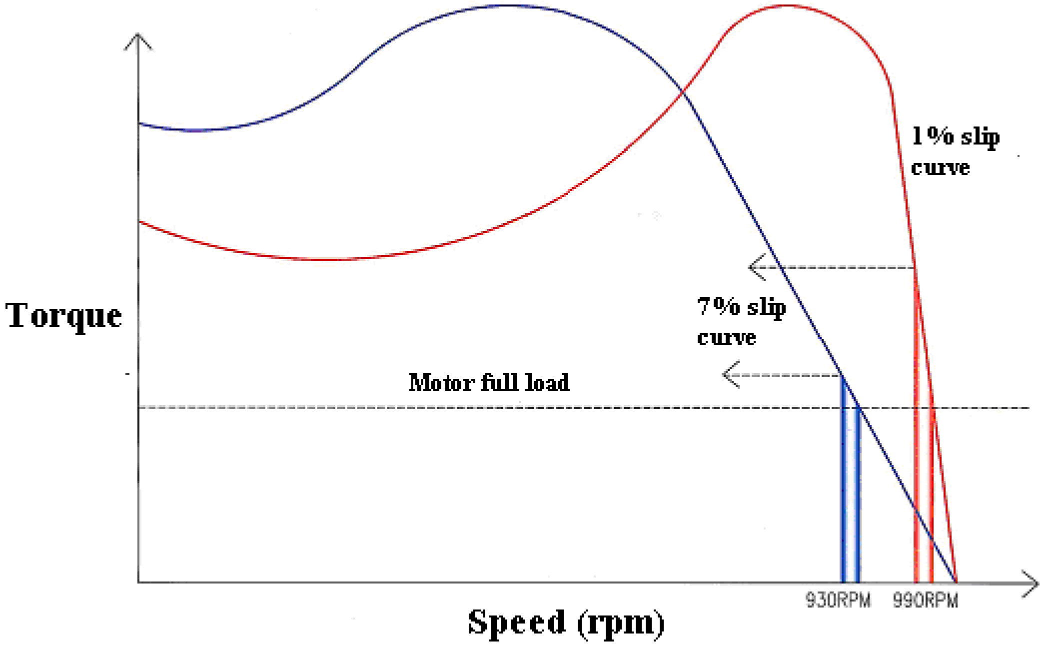

Figure 1. Speed versus torque of shredder drives.

Factors that cause excessive shredder power swings

Apart from stiff drive characteristics there are a number of other factors that have a greater or lesser effect on the load swings demanded by shredder drives and their impact on the mill power houses.

These are:

1. The shredder internals which affect the windage and potential hanging up of the cane feed.
2. The uniformity of the cane feed to the shredder (this was not particularly regulated at Felixton mill (Boshoff, 1986, unpublished)).

3. The speed of the shredders (once again Felixton, at 1200 rpm had the most trying condition).

4. The number of cane preparation lines, i.e. the number of shredders where one shredder drive can pull down the power house frequency due to a sudden power demand. The second shredder drive sees this as a change in speed and starts to correct when it is suddenly hit by its own power demand. It is easy to see that the whole system could become unstable.

5. The size of the power houses in relation to the shredder ratings (the larger the better). Felixton power house was 30 MW and the two shredders were 6 MW (5:1). TSB power house was 20 MW and the two shredders were 5 MW (4:1).

6. The size of the standing load on the power houses in relations to the shredder loads, i.e. the electrical inertia (the larger the better). Felixton was ±16 MW and the two shredders were ±5 MW (3.2:1). The TSB power house was ±14 MW and the two shredders were ±4.5 MW (3.1:1).

7. The type of governors on the steam turbines in the power house and the type of Automatic Voltage Regulators (AVRs)on the alternators. Modern governors and AVRs, with their high speed electronics, have improved the ability of this equipment to compensate for sudden step changes in the required output.

8. Whether or not the power house is connected in parallel with the national grid under a Cogeneration Agreement (the National Grid helps absorb the power swings).

Case Study: The Dombe Ethanol and Cogeneration Facility (DECG)

Description of project

The DECG is a proposed ethanol from sugarcane facility to be built west of Beira. The owners are Mozambique Principal Energy and the designers and project managers are Bosch Projects.

The DECG is a green field site and provides an opportunity to adopt this new approach, in that.

- The facility is being designed for billeted cane with medium duty cane knives which should provide an even and uniform cane feed.

- It will have only one cane preparation line with one 3.5 MW shredder drive.

- It will have a large installed power house, initially 36 MW (10:1).

- It will have a large standing load 30 MW due to the irrigation and estate load (10:1).

- It will incorporate the latest technology for the turbine governors and AVRs.

- It will eventually be connected to the Mozambique National Grid.

The proposed shredder drive solution

Initially an MV AC drive 3.5 MW, 11 kV input 6.6 kV output VSD, to a 3.5 MW, 6.6 kV, 6-pole squirrel cage motor was proposed. This solution proved to be prohibitively expensive.

The second idea was an MV AC drive with a 3.5 MW, 11 kV to 6.6 kV, 18 pulse transformer, 6.6 kV input and 6.6 kV output variable speed drive (VSD) and the same motor. This was cheaper, but still more than a slip ring solution.

The third was to make use of a squirrel cage pony motor of 800 KW, 400 V, 6-pole coupled to one side of the shredder using Cardan shaft and a main motor 2.7 MW 11 kV 6-pole squirrel cage motor coupled to the other side. The pony motor would be driven by an 800 kW 400 V VSD whilst the main motor would be switched in DOL, once the shredder has reached full speed.

The pony motor could then be switched off during periods of low throughput or left in circuit assisting as a slave motor to the main motor, under torque control, ensuring a sharing of the load in relation to their ratings (refer to Figure 2).

The cost of this proposal including the civil work was estimated to be R1.5 million and was less expensive than the slip ring solution (refer to Table 1).

Table 1: Various solutions and estimated prices (Rands).

Items of equipment	Slip ring motor solution	VSD solution	Pony motor solution
11 kV circuit breaker/contactor	175 000	175 000	175 000
3.5 MW, 11 kV 6-pole S/R motor	4 250 000	4 250 000	
2.7 MW 11 kV 6-pole S/C motor			1 800 000
800 kW 400 V 6-pole pony motor			620 000
Liquid starter and resistance bank	850 000		
Robicon VSD 11 kV in 6.6 kV out		7 460 000	
400 V 1600 A switch			60 000
800 kW 400 V VSD			1 000 000
Cabling and racking	200 000	150 000	250 000
Motor base civils	400 000	400 000	500 000
Totals	**5 875 000**	**1 2435 000**	**4 405 000**

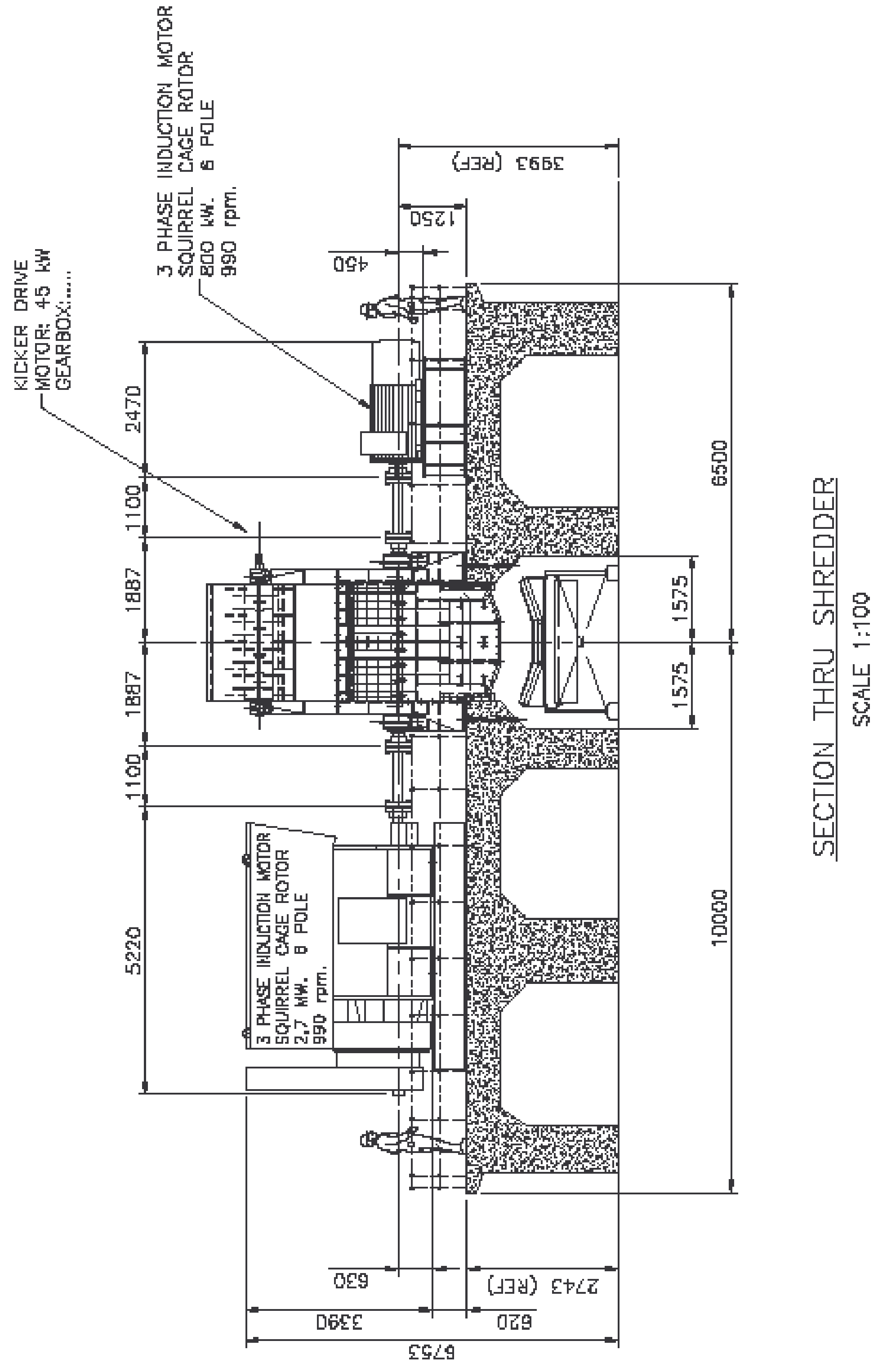

Figure 2. The Dombe ethanol and cogeneration shredder design.

The proposal has the following advantages:

1. The 800 kW LV motor and VSD were chosen for compatibility of spares:

   The two ID fan motor ratings will be 800 kW, 400 V with VSDs.
   The two mill drive ratings will be 800 kW, 400 V with VSDs.
   The cane knife set is also a tandem drive configuration with two 800 kW, 400 V motors and VSDs.
   The Hogger motor for wood shredding will be 800 kW, 400 V with VSD.

2. Both main and pony motors are inexpensive, robust and almost maintenance free squirrel cage motors.

3. The VSDs being 400 V are standard, proven, and robust and virtually off-the-shelf items.

4. There would be an 800 kW motor as a spare in store.

5. There would be an 800kW 400V VSD wired as an equipped spare in the cane preparation substation.

6. Should the main motor fail, the spare 800 kW motor could be installed in its place on an adaptor baseplate and cabled up to the equipped spare VSD. The shredder power would only be 1600 kW, but the system could still run at either a reduced PI or reduced throughput.

Conclusions

This proposal generated a great deal of debate in the Dombe team, but it is believed that the best all-round balance in terms of technical, operational and budget requirements have been achieved.

However, this is not to say this solution is the best for every sugar mill. The design of each new shredder drive has to be evaluated in terms of its own particular set of circumstances.

REFERENCES

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