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Optimization of the drive system for a cyclone feed pump

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Introduction

Beneficiation of ores and minerals in a concentrator plant requires a significant amount of water [1] for the grinding and particle separation processes; most of it ends up being recirculated for reuse, slurry pumps are used after crushing and grinding feeding the ore to a classifier to separate fine-grained material (less than 5 mm) from coarse-grained material requiring further grinding. The lower ore grades [2] in the past couple of decades have demanded an increase on power size and efficiency of process machines to maintain a competitive plant throughput; Hydro-cyclone feed pumps to control both under and over milling or grinding are not the exception; Fig. 1 shows a conventional drive train [3] comprising an (1) asynchronous motor (also known as squirrel cage induction motor = SCIM), a high speed coupling (2), a gear reducer (3) and a low speed coupling (4) attached to the shaft of the pump (5), to accommodate the motor rated speed (typically 1800 rpm) to the process requirements (in the range of 250 rpm to 350 rpm), requiring additional components related to the gearbox: instrumentation, maintenance, disposable lubricants and filters, spare parts, thus reduces the overall system efficiency ultimately reflected into CAPEX and OPEX.

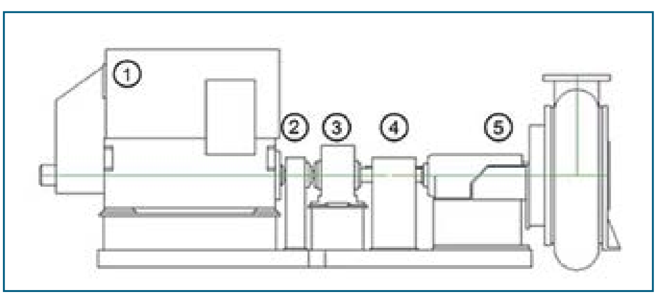

Figure 1: Mechanical drive train of a large cyclone feed pump [3]

Why Variable Speed Drives for Cyclone Feed Pumps

Hydrocyclones or commonly referred as "cyclones" are one of the most important devices in the minerals industry [4]; almost universally used in close-circuit grinding because of their high capacity and relative efficiency, the evolution of Power Electronics made affordable the use of Medium Voltage – Variable Frequency Converters (VFC) for Cyclone Feed pumps in combination with induction motors larger than 500 hp (373 kW) to gain multiple benefits:

- Soft start with minimum electrical utility disturbance = inrush current mitigation
- Full Torque available at zero speed for overload startup with pulp solidification after long still stand periods, superior to any other reduced voltage starting method.
- Optimum and constant pump speed (independent of the electrical network or load condition), compared to across the line SCIM operation
- Flexible Motor Voltage and Speed regardless of the power distribution Voltage and Frequency
- Improved Power Factor (close to unitary), over the entire operating speed range

Fig. 2 shows a block diagram of most common [5] Medium Voltage – Variable Frequency Converters. The first stage is an input conversion circuit which rectifies the utility three phase AC electrical power with constant voltage and frequency into DC; the second stage the output inversion changes the DC back into AC with variable amplitude and frequency, the additional elements shown are devices commonly used for the optimization VFC performance.

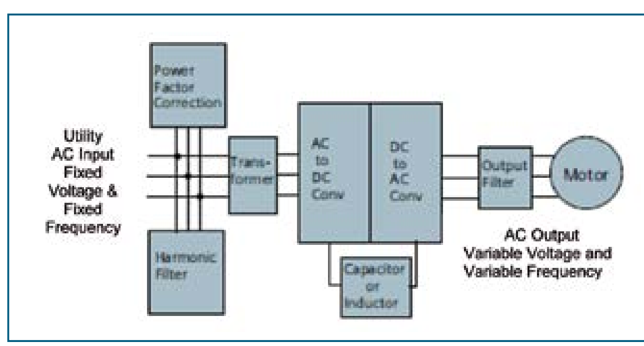

Figure 2: Structure of a generic VFC [5]

A Cyclone Feed Pump is a variable torque load with power behavior depending on the impeller speed similar of a centrifugal pump; Fig. 2 shows the Torque and Power Curves in function of the impeller speed of a 3000 hp cyclone feed pump, a speed reduction inserting a VFC in the motor electrical circuit brings significant power savings, for instance:
at 90% of rated speed the pumps with torque and power to speed characteristics shown in Fig. 2 would consume from the utility only around 72% of its nameplate power.

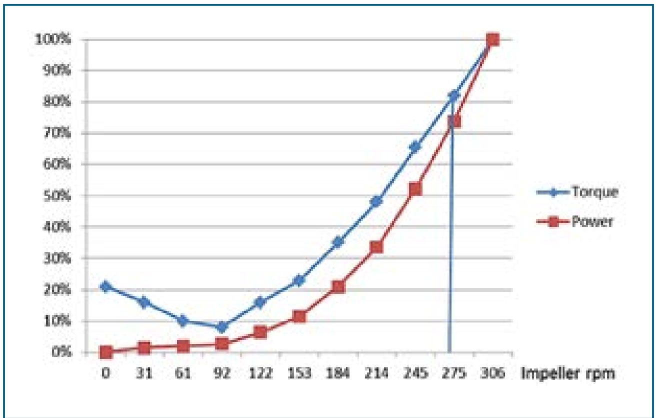

Figure 3: Power and Torque [%] characteristics in function of the speed [rpm] of a slurry pump

Optimization of the Drive System

The feed to a cyclone shall be as stable as possible regarding both pulp density and volumetric flow rate; unsteady conditions like extreme variations in slurry density or severe pump surging play against a good cyclone performance [6]. Currently the prefer way to operate large cyclone feed pumps is through an Adjustable Speed Drive to maintain constant flow compensating fluctuations in the electrical network or load condition affecting the motor speed; In other words the quality of a particle separation process relies on an stable and constant speed at the motor shaft, furthermore the induction machine does not operate across the line to keep for the operator the ability to adequate the speed according with the process needs. Using the key features of a VFC; the electrical drive train can be optimized to provide the required torque directly to the pump shaft without need of a mechanical speed reducer, Voltage, Frequency and number of poles of the induction motor can be engineered to maximize the system performance [7]; eliminating at same time a high speed coupling, temperature, flow and vibration instrumentation typically utilized for condition monitoring of large size gearboxes. The more components subject to wear we omit in the drive train, the larger its reliability and consequently the less the need of maintenance.

Case Study- Application of Squirrel Cage Induction Motors Direct Coupled to cyclone feed pumps without gearbox.

Two cyclone feed pumps 3000 hp each direct coupled to an induction motor 327 rpm started operation middle of 2014; in a copper molybdenum concentrator plant located in USA, Fig.4 depicts the simplified drive train consisting of an induction motor (6) direct attached with a low speed coupling (4) to the pump shaft (5).

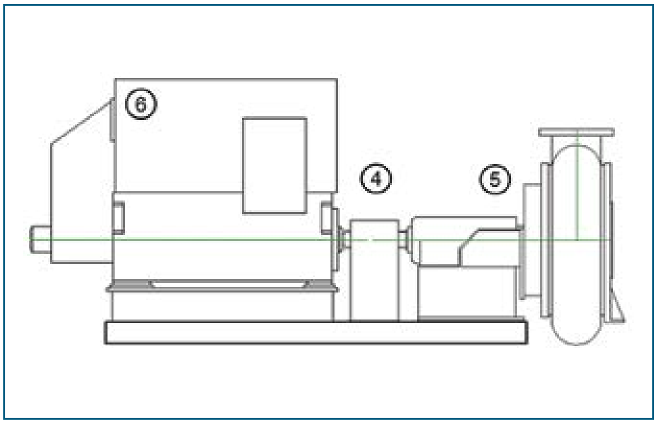

Figure 4: Sketch of a direct couple low speed SCIM for a large cyclone feed pump [3]

Rated to operate at a maximum ambient temperature of 113°F (45°C) in an elevation of 4147ft (1264 m), a compare with the traditional geared drive train is provided, Table 1

	Geared Induction Motor	Direct Coupled Induction Motor
Power	3000 hp	3000 hp
Service Factor	1.15	1.15
Rated Voltage	4000 V	4000 V
Full Load Speed	1791 rpm	327 rpm
Enclosure	TEAAC	TEAAC
Frame Size	8010	716
Approx. weight	23000 Lbs.	52470 Lbs.
Rated Current	371 Amps	409 Amps.
Motor Efficiency	95.7%	96.0%
Power Factor	0.91	0.82
Full Load Torque	8813 lb-ft	48183 lb-ft
Starting Torque	68% FLT	113% FLT
Breakdown Torque	244% FLT	259% FLT
Bearing type	Anti-Friction	Anti-Friction
Overall drive* Efficiency	92.8%	96%
Energy consume 350 days/year	20,258 MW-hr	19,582 MW-hr
Savings/year	–	675 MW-hr

Table 1: Technical Data and Efficiency compare of a geared vs. a direct coupled 3000hp drive train

Initial Investment

The Customer conducted a due diligence regarding the Capital Expenditure; as result the decision was in favor of a direct couple low speed SCIM, considering the energy savings, enhanced reliability and reduced maintenance cost. Although in appearance the initial investment of drive trains with gearboxes seemed to be lower; in the long term the Return of Investment of a direct coupled motor resulted superior, while comparing different Adjustable Speed Drive solutions; the Capital Expenditure (CAPEX) should look at the whole picture including lubricants, disposable materials, installation labor / supply of for other auxiliaries like supervisory PLC, Motor Control Center (MCC) and instrumentation associated with the gearbox. A direct coupled "low speed" motor has to produce a larger torque than a traditional geared one; therefore its frame size is larger and engineered accordingly, consequently the initial investment of a direct couple SCIM is similar than the VFC, Table 2. The direct coupled SCIM only requires bearings as spare parts; been pretty standard, do not need to be sitting in the Client's warehouse till next replacement cycle in contrast to long term delivery mesh girth.

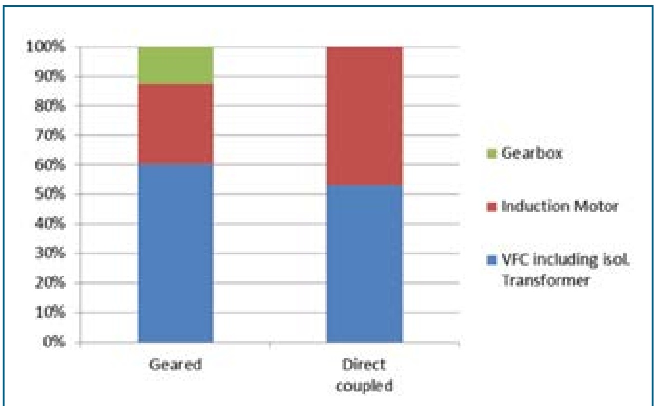

Table 2: CAPEX of geared (1791 rpm SCIM) vs.
Direct Coupled (327 rpm SCIM) 3000 hp

Efficiency

The overall efficiency estimate of the gearbox considers for simplicity: its lubrication pump, oil cooling system and friction losses. The power factor of the SCIM is compensated in any case by the VFC therefore close to 0.95 in front of the drive.

Reliability

The direct coupled drive systems of both 3000 hp Cyclone Feed Pumps have been running since June 2014; without any reported downtime due to electrical drive train issues. Although it seems to be early for this particular case in U.S.A. to draft additional conclusions, there are similar reference installations located in South America operating satisfactorily since 2001. Every mine operator can estimate the reliability factor associated with large gearboxes in the long term, particularly running over rated production capacity and its yearly maintenance cost including lubricant replacement.

Conclusion

Large cyclone feed pumps include nowadays a VFC as part of their electrical drive system; the benefits of an Adjustable Speed Drive can further be enhanced omitting the mechanical speed reducer or gearbox, traditionally installed between the induction motor and the impeller shaft, sizing the electrical drive train to match the impeller rated torque and optimum speed for the ore separation process. Consideration should be given to the novel approach of a direct couple SCIM to the pump impeller shaft based on the energy, labor and other collateral raising costs continuously stressing both CAPEX and OPEX in mine operations.

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Notice

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