INSURABILITY OF LARGE GEARLESS MILL DRIVES

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ABSTRACT

The availability and reliability of large grinding mills and their Gearless Mill Drives (GMDs) are of paramount importance for the grinding process. Although GMDs have been in service for decades, and are known for their operational efficiency (reliability and robustness with reduced operating cost per ton), compared to conventional drives, in the last decade due to certain reasons some failures led to serious unscheduled shutdowns and significant insurance events.

The majority of these notable "insured" failures have happened on GMDs installed on relatively large mills, as the financial impact of a failure is proportional to the through-put of the mill. Despite the occurrences of these events, as mining operations are driven by lower ore grades and the ability to continue reducing operating costs per ton, the trend for having larger mills is still very present and there is no reason why this trend should not continue.

It is obvious that if not handled correctly, the possibility of large value GMD loss events, coupled with the continuing increase in mill size or required availability and reliability targets, could potentially lead to major conflicts as it becomes difficult for the insurance companies to judge the risk and hence may result in hesitation to insure these grinding circuits. This paper will not only describe the conflicting situation from both an insurer's perspective and from an equipment supplier's perspective, but also how these conflicting challenges can be successfully mastered. It has to be noted that not only the mining companies themselves, but also their insurance companies and the involved equipment suppliers have a common interest: to reach the highest availability and reliability in order to avoid or at least minimize unscheduled shut down times, and most importantly prevent unplanned events that result in extended production stoppages or reductions in through-put of GMD driven mills.

From the very beginning onwards, the complete service concept together with emergency plans must be integrated on every level in the design of the grinding circuit. This approach must be implemented continuously and without compromises by all involved parties during all following stages, such as basic design, detail design, manufacturing, quality inspection and testing, packing, transportation, storage, installation, commissioning, operation and maintenance. The concept of formal risk analysis related to mill operations, maintenance and spare parts strategies must be an integral part of mining companies' decisions related to the selection for installation and continued use of large mills powered by GMDs. The service concept in place for operating mills shall also have a clear focus on very early detection of any abnormalities, so that the risk can be mitigated and unscheduled shutdown times avoided. However, if a major failure occurs, then procedures and tools shall already be available in order to ensure that production impact is minimized.

KEYWORDS

Mills, gearless mill drives, insurance

INTRODUCTION

Mining is considered a complex, energy intensive industry, as seen by the global insurance market. The complexity of the industry from the insurer's perspective is based on the broad scope of loss potential, or risk. Risk is present in many different aspects of mining, including environmental, employee health and safety, third party, physical damage to assets, equipment breakdown, and the associated loss of income that may result following an insured loss. During the last decade some significant losses have occurred in the mining industry, specifically related to large GMD mill installations. These losses have led, not surprisingly, to increased visibility of the risks related to these large mills by the insurance industry. An increasing loss frequency can bring questions to the insurers regarding the insurability of installed GMD driven mills if they are not properly maintained. Furthermore, looking towards the future, certain reluctance may exist for the insurance industry to participate in providing coverage for new, even larger GMD mills, than those in service today. On the other hand, there is a clear trend in the grinding industry for larger and more powerful mills. In order to avoid the unacceptable situation of having a too limited possibility to attain an adequate and acceptable insurance coverage, the risk management of both the existing and future, larger GMD mill installations have to be thoroughly addressed.

MINING INDUSTRY FROM THE INSURERS PERSPECTIVE

The global insurance industry provides risk transfer solutions to the mining industry in all of the various areas where risk is present (environmental, employee health and safety, third party, physical damage to assets, equipment breakdown, and the associated business interruption loss). The discussion contained within this paper provides an insight on the mining industry from the insurer's perspective, and more specifically how the mining insurers evaluate mining risks related to property damage, equipment breakdown, and associated business interruption exposures. Finally, this section will focus on how the insurers view the specific risks related to large Gearless Mill Drive (GMD) mills, and why the insurability of these large mills is a significant concern to the mining industry that utilizes them, the manufacturers that design and construct them, and the insurance companies that provide coverage to the users.

Introduction to Risk Management

The term "risk" is used ever more frequently today as is illustrated by the broad spectrum of topics where it is frequently referenced. Examples include discussions related to business operations, workplace safety, financial investing strategies, medical procedures, to discussion on raising children. And since it used so frequently, it is important to begin a paper discussing insurability by providing an accepted definition of the term risk.

Risk can be described as "an assessed loss potential". Written as a mathematical function, risk can be shown as:

$$R = f(S, P) \tag{1}$$

Thus, the Risk (R) associated with an activity is a function of the Severity(S) of the resulting loss condition and Probability (P) that the loss outcome will occur.

Understanding the above definition of risk, it is accepted that mining is an industry in which risk is present in many different aspects. The existence and acceptance of risk is commonplace in the mining industry, principally because along with accepting the risk there is typically great opportunity for reward. In most cases, if the risk is properly managed, the resulting payback from the opportunity more than compensates for the accepted risk.

Thus, the need for effective risk management solutions is required to confidently approach and achieve success in any business opportunity. There are various methods of effective risk management, all of which begin with evaluating the risk. Once the risk is understood, it can be managed through mitigating actions, which can either remove some aspects of risk entirely, or at a minimum reduce the probability or severity of the risk, such that it is acceptable. However, in some instances, there may be no way to effectively eliminate or reduce the risk, such that it is completely acceptable to the company. When this occurs, the purchase of insurance can be an effective method for companies to manage the risk associated with their business activities. Insurance is effectively transferring the risk associated with their business to another entity (i.e. the insurers).

Insurance Underwriting of Mining Risks

The complexity of providing insurance to the mining industry is driven by the wide range of hazards and risks present within the industry. Potential for loss exists in multiple areas of the mining process, ranging from the ore extraction activities, mineral processing methods, large facilities and mine infrastructure, critical supply exposures, and process waste disposal. The mechanisms that can result in a mining loss cover a wide range, including fire, mine flooding, geotechnical failures, structural failures, machinery failures (electrical or mechanical), contingent supply interruptions, and natural catastrophe events (earthquake, flooding, wind, etc.) just to name a few. The specific risks present at any one mining operation are driven by the methods of mining and processing, as well as the physical location and configuration of the mine.

The wide range of complex activities where risk exists presents several potential loss scenarios for which the resulting physical damage to property can be significant. An insured loss is predicated by an event occurring that results in physical damage being inflicted to an insured asset. The resulting physical damage has an associated value of loss, which is determined by the cost to repair or replace the physical asset. Depending on the area of the loss and the magnitude of the damage, the value of this loss can reach into the millions to tens of millions of dollars. However, the driving dynamic behind the largest of mining related losses is the associated business interruption (BI), or loss of budgeted revenue as a result of not being able to produce at the planned rate. Depending on the specific commodity that a mine is producing, and the percentage of production and length of time in which production is curtailed, a single loss can reach into the hundreds of millions or even billions of dollars (USD).

The structure of a mining property insurance program is typically developed by the mining companies, working with their insurance broker. The broker and mining company will evaluate the risks of their operations, and determine to what level they desire to retain or transfer risks, the limits of the coverage, as well as the specific lines of coverage. The insurance submission developed by the broker and mining company is submitted to the various “mining” insurers for consideration in providing the requested coverage.

Given the gross magnitude of loss potential within the mining industry, it is common practice that multiple insurers will participate on a single mining company’s insurance program, each taking a share of the coverage. The size of the participation is based on each of the various insurance companies’ capacity to provide coverage, as well as their appetite for the specific risks present for the company seeking insurance.

Engineering Assessment of Mining Risks

A detailed understanding of the mining risks present, and how they are managed, is important for insurance underwriters, in order to effectively participate on providing coverage for a mining company. To facilitate the understanding of the risk, the insurance industry utilizes “Risk Engineers”, with broad knowledge of the mining industry to assess the mining exposures of a given company. This entails the conduct of mining risk assessments, by the Risk Engineer, at the mining operations for which insurance coverage is being sought.

The key purpose of a mining risk engineering assessment can be stated as: “Identify exposures and loss potential which might result in property damage, machinery breakdown and business interruption.”

The key activities completed during the risk assessment include:

- Review of the mine and process configuration, operational capacities, current production plan, recently completed and future projects
- Fire protection system installations review (adequacy, reliability and condition)
- Electrical/Mechanical Maintenance program review
- Critical Spares review

- Contingent Supply exposures (power, water, etc.) review
- Review Loss Control and Business Continuity planning.
- Review of exposures to extended mining perils s such as mine flooding, fall of ground, pit slope failure, and tailings impoundment failure, and natural catastrophe perils such as earthquake, tsunami, windstorm, flooding, etc.

During the mine risk assessment, the Risk Engineer will conduct tours of the key operational areas and infrastructure, observing:

- Equipment configuration and condition (mechanical and electrical) for critical equipment
- Structural conditions of facilities
- Hazards associated with fire (i.e. lube rooms, conveyors, electrical installation, flammable/combustible materials, and fire response/protection capabilities)

During the assessment, if the engineer identifies areas where there is potential for the site to improve the exposure and reduce risk, he may offer advice to achieve improvements.

Following completion of the on-site risk assessment, the engineer develops a detailed written report, describing the operations of the site, critical equipment and infrastructure, sites management of key risks, establish an "opinion" or "ranking" of the risk, and establish loss scenarios which are considered the worst credible loss scenarios for the operation, involving insured perils.

The loss scenarios developed in the mining risk assessment process are an important aspect of the underwriting of a risk. The worst case loss scenario is commonly referred to in the industry as Estimated Maximum Loss (EML) or Maximum Foreseeable Loss (MFL). Zurich utilizes the EML as a key component in the underwriting decision, and has established the definition of EML as:

The largest monetary loss (property damage plus business interruption) within one fire division that may be expected to result from a single fire when this is the governing factor, or other insured perils, with fire protection impaired and the control of the fire is mainly dependent on physical barriers or separations and delayed manual fire fighting by public or private fire brigade.

This is a definition that spans across the entire spectrum of insured locations, and is not specific to any specific industry. The wording of the definition largely focuses on fire events, as in a vast majority of industries; fire is likely the leading loss scenario. However, the mining industry has many other large loss scenarios, which can potentially exceed the worst case fire event. These scenarios are captured within the definition by the phrase "or other insured perils". Examples of non-fire related loss scenarios that could be considered as possible EML events include:

- Major slope failure in a large open pit.
- Losses involving underground access (shafts, declines, etc.)
- Mine flood events
- Machinery Breakdown losses associated with critical equipment with long lead times for replacement components (mills components including GMD motors, conventional mill girth gears, electrical system components such as transformers).
- Structural failures involving key process plant areas
- Tailings impoundment failures.

As noted previously, the loss severity in the mining industry is ultimately determined by the business interruption associated with the loss event. The drivers for business interruption include the percentage reduction in through-put as a result of the loss, the length of time that the reduced production will be experienced, and the commodity price at the time of the loss. The existence of redundancy in the mining and processing areas, and the holding of critical spares are factors that can have a direct impact on reducing the EML of an operation. The loss scenarios are a key component in understanding the "Severity" component of the "Risk" function described earlier.

In addition to establishing the loss scenarios, risk engineering assessment report contains an assessment of the sites' maintenance, engineering, supplies, and other key management programs is conducted. These are important aspects of the risk assessment, as this provides an evaluation of how the site manages the risks associated with the key loss scenarios. While the value of the EML may not be greatly influenced by these programs, they must be taken into consideration as they provide indicators of the potential likelihood that a loss may occur, and also how well the site can respond to mitigate the magnitude of the loss. The evaluation of these critical risk management programs provides an understanding of the "probability" component of the "Risk" function. For instance, if the site has good maintenance programs, which includes sound predictive and preventative maintenance activities, the likelihood of an unexpected machinery breakdown failure is reduced. Similarly, if the site has good practices in place for hot-work control, housekeeping, and control of combustibles and flammables, the likelihood of a major fire caused by hot-work is reduced.

This detailed risk assessment report is then utilized by the underwriters at the various insurance companies in the decision making process when providing a quote to the coverage requested by the mining company and their broker. While not the only factor used by the underwriter in making decision, the report can influence the underwriter's decision to participate on an account in many ways, including whether they will provide coverage at all, to the amount of capacity they provide, and the associated premium rates for the coverage. Additionally, an insurer may request policy wording modifications, deductible limits, coverage limits, or exclusions from coverage may be requested based on specific, extremely negative findings.

Risk Factors Pertaining to Insurance Rates

There is no single "insurance premium" equation that is used through-out the insurance industry. An insurance company will have a methodology, which they use to establish a rate that corresponds to their comfort with providing coverage to the level of risk being insured. What can be discussed is that there are multiple factors that can influence the rate. Some of these factors are controlled directly by the customer, some of these factors are provided from the results of the Risk Engineering Activities, some of the factors are controlled by the physical location of the risks (i.e. natural hazard exposures), and some factors are driven by the current insurance market.

There are several decisions relating to the type and level of coverage sought that the mining company has control over when establishing their insurance program; which directly influence the insurance premium. These decisions include the retained deductible for physical damage, as well as the wait period that must be satisfied prior to the insurance providing business interruption coverage. Higher deductibles and longer waiting periods can reduce the insurance premium, but in turn increase the uninsured exposure for the mining company (increasing their retained risk). Additionally, the mining company can also place limits on various coverage items within the insurance program, such that losses will only be paid to the limit. Finally, the customer can remove specific coverage items from consideration, through exclusions, which can reduce the premium.

As discussed previously, the risk engineering assessment provides inputs into the determination of the premium. The severity aspects of the risk are quantified through providing the potential loss scenarios (EML). The probability aspect of the risk "rating" or "engineering opinion of the risk", which identifies how the site manages the specific risks in order to reduce the probability of a loss occurrence. While these factors are developed by the engineer, they are based on information collected and conditions observed during the conduct of the site visit, thus the mining company is ultimately able to provide positive impact on the rates through effective risk management programs, as these will be reflected in the "rating" established by the Risk Engineer.

The physical location of a mine which results in the susceptibility to natural hazards perils such as earthquake, flooding, tsunami, wind-storms are risk factors that can have an impact on insurance rates. Within the insurance industry, there have been catastrophes models developed which are used for determining rates for insurance for wind, earthquake, and flood. This is an area that continues to be refined, as new data is obtained from actual natural catastrophe events worldwide, and the models are updated accordingly.

Finally, there are market related factors that can also influence insurance premiums. There can be different forces at play in the market that influence rates. The availability of "capacity" within the market has a direct impact on rates. This is a "supply" and "demand" based factor, and as more capacity becomes available (i.e. additional insurers enter the mining market), then rates tend to decrease. Should capacity be reduced (i.e. some insurers decide to no longer provide coverage in the mining market) then rates can increase. Mining industry losses are another market based factor that can influence rates. If a significant number of losses occur in a given time-period, some insurance companies may decide to leave the mining market, causing an abrupt reduction in available capacity. This loss- related shift can cause an increase to the entire mining industry. The loss factor can be compounded if a loss is significant and can be tied to a specific method, process, or type of equipment. A loss of this nature can cause rates of companies with similar configurations to experience a rate increase.

Insurance Industry concerns with Gearless Mill Drives

The previous section has been developed to provide a general understanding of the Insurance Industry overview on how it assesses mining operations as part of the underwriting process. It has been presented that the "Severity" of potential loss scenarios and the "Probability" of the loss occurring are key drivers in determining how an insurance company may participate on a mining company's insurance program.

From a mining/processing operations perspective, the Gearless Mill Drives are a valuable piece of equipment since high through-put that can be achieved in a single milling line. While this high process efficiency is beneficial to the mine production rates and costs, from the insurers' perspective, the high milling rates associated with GMD mills, when combined with high commodity prices present significant loss scenarios values. In addition, there have been several losses associated with GMD mills in recent history. The potential severity of the GMD loss scenarios, coupled with the loss history have raised the level of attention that mining insurer are giving to this method of milling. The risk associated with GMD's is a critical item that must be considered by the insurers when providing coverage to mining operations that use this technology.

As mentioned previously, at current commodity prices, the business interruption component of a loss can be significantly larger than the physical damage component. Considering that the through-put for a large GMD mill can range from 40,000 tons per day (tpd) to in excess of 100,000 tpd, for the largest of mills. At current commodity pricing, the daily business interruption (BI) rate associated with a 60,000 tpd GMD mill can range between 4 MUSD (US$ 4M) to an excess of 7 MUSD (US$ 7M) per day for a large copper mine. The variance in daily BI is dependent on the ore type (metals present in ore), ore characteristics (hardness), as well as the head grade of the ore that is being mined. These illustrative figures have been calculated utilizing an assumed ore grade of 1% Cu, for a copper only ore body, in order to determine the low range value. The upper range of the daily BI value has been determined by considering a copper ore body, which contains other metals such as gold, silver, molybdenum, zinc, or other secondary metals which add value to the base copper concentrate. The actual daily business interruption value for any mine is dependent on the actual ore grade and metals contained, plant through-put rates, as well as fixed costs and labour costs, which are also included in the insured business interruption rate. The values provided here are mainly to illustrate that the losses associated with a GMD mill can be staggering. As components within a large mill can have lead times in excess of 12 months, the worst case loss scenario for a mill failure, when spare components are not held on-site, the gross loss can grow into the billions of dollars (USD).

While the great loss potential associated with the GMD is a concern within the mining industry, it is not the only item that raises the question of insurability. As mentioned previously, loss history can also weigh in on the question of insurability. Additionally, future changes within the technology also cause concern for insurers, specifically, the potential for increases in the size of mills being powered by GMD's, as this can bring increased through-put, and the unknowns related to potential new failure mechanisms created by the increase in size.

The discussion of this paper to this point has been aimed at developing an understanding of how the insurance industry approaches the mining industry in general, and secondly to lay the ground work for further discussions related to the question of insurability for large GMD's. To further the discussion, it is now timely to shift discussion specifics regarding GMD functionality, design, operations, and maintenance, as presented by a GMD manufacturer. Upon developing an understanding of GMD specifics from the manufacturers' perspective, the final section of this paper presents information on how the insurer's Risk Engineers evaluate GMD installations with respect to insurability.

BRIEF OVERVIEW GEARLESS MILL DRIVES IN THE MINING INDUSTRY

The gearless motor (also called wrap-around motor or ring motor) is a very large synchronous motor. The poles of the motor are directly installed on a pole flange on the mill shell; this means the mill body becomes the rotor. The stator of the gearless motor is then wrapped around the mill. Refer to figure 1 for an overview of the mill and the gearless motor.

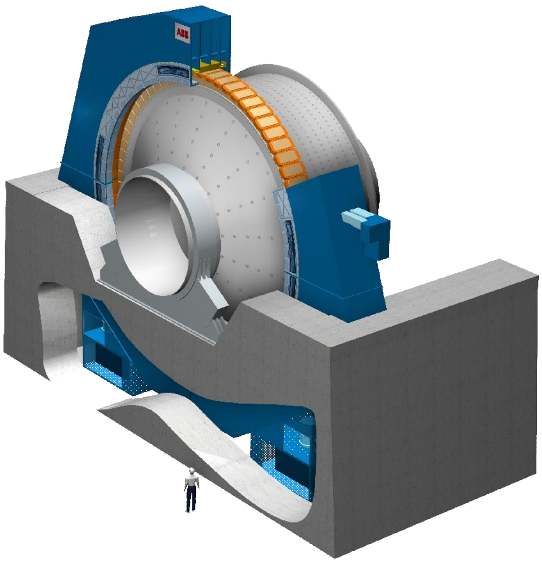

Figure 1 – The gearless mill drive

With this innovative concept, the gearless mill drive (GMD) eliminates all critical mechanical components inherent within a conventional mill drive system, such as ring gear, pinion, gearbox, coupling or air clutch, motor shaft and motor bearings. Eliminating such components significantly increases the efficiency and the availability of the mill. The gearless motor is fed by a cyclo-converter which allows the operator to easily vary the mill's operational speed. ABB (then BBC (Brown Boveri & Cie), before the merger with Asea) installed the world's first GMD in 1969. This 6.4 MW GMD powered a 16 ft diameter cement mill in Le Havre (France), which today, 42 years later, is still operating; therefore the principle of the gearless mill drive can absolutely be considered as proven technology.

Power Density

In the 1980s, the GMD was introduced to the minerals market as the powerful and reliable drive system for SAG mills. Early SAG mills had a diameter of approximately 32 ft, later increasing to 34, 36, 38 and 40 ft. The same applies for the ball mills, which continuously have been increasing in diameter. At the same time also the mill lengths and ball charges increased, leading to more powerful GMDs in relation to the mill diameter. With the following two examples we explain what is meant by this:

- The world's first two 40 ft diameter SAG mills have GMDs installed with rated powers of 20 MW (Cadia) and 21 MW (Collahuasi). Nowadays, several 28 MW GMDs are being manufactured or have been already been delivered for 40 ft diameter mills.
- The world's first 26ft diameter ball mill was equipped with a 15.5 MW GMD (Collahuasi). For other 26ft ball mills afterwards, the corresponding rated power of the GMD went up to 17.5 MW.

The trend shown by these two examples for 40ft and 26ft mills are basically applicable for all mill diameters in the mineral industry; over time the so-called "power density" of the newly ordered GMDs increased. The GMD power density is the relation of installed power [MW] over mill diameter [ft]:

$$\text{GMD power density} = \frac{\text{mill rated power } [\text{MW}]}{\text{mill diameter } [\text{ft}]} \quad (2)$$

Figure 2 shows the power density values for (S)AG and ball mill GMDs ordered from ABB during the last 15 years.

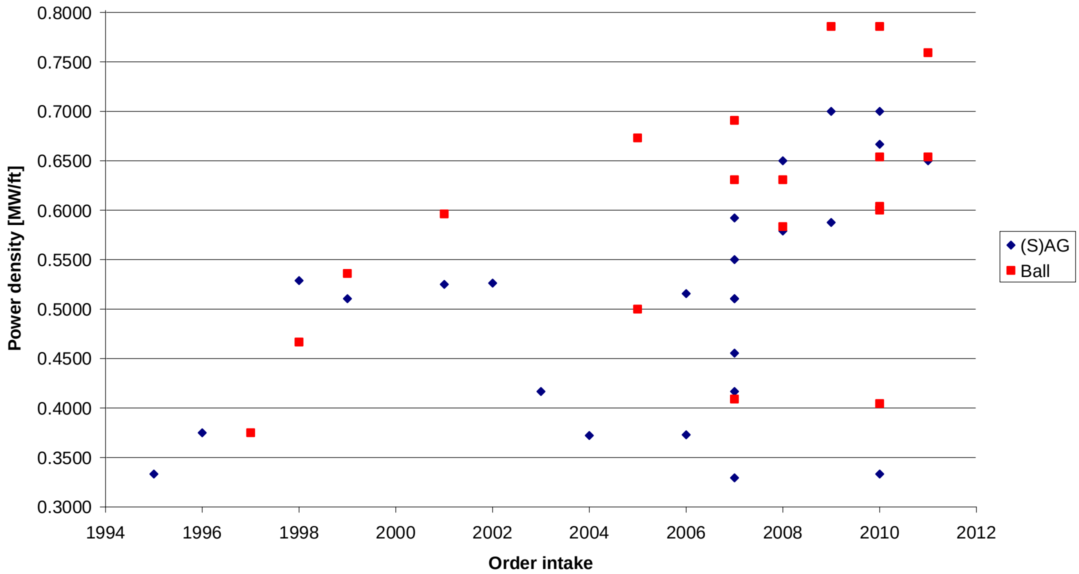

Figure 2 – Power density values of GMDs sold by ABB the past 15 years

There are several reasons for this trend of higher power density values, such as longer mills, higher ball charges and lower grade ore bodies. Obviously the power density can also have an impact on the design of the GMD. More power means more active material in the motor. This means the motor size must increase; but the gearless motor cannot, unlike conventional electric motors, be increased in radial direction ("increasing shaft height"), as then the pole flange would become too high. Therefore the gearless motor can basically almost only increase in axial direction. In other words, a higher power density value results into a wider motor (in axial direction).

Not only the power density, but also the rated power requirements of the GMDs have been continuously increasing over time. The world's most powerful GMDs currently in operation are the ABB

GMDs for the Esperanza SAG mill in Chile (a 22 MW GMD for a 40 ft SAG mill) and for the two huge AG mills (two 22.5 MW GMDs for two 38 ft x 45 ft AG mills) at Aitik in northern Sweden, above the arctic circle. These AG mills at Aitik are from a volume point of view, with the astonishing length of 45 ft, the world's largest mills. The massive scale of this installation is shown in figure 3.

Figure 3 – One of the two 38ft x 45 ft AG mills at Aitik, Sweden

However, there appears to be no limit: ABB last year delivered to Minera Chinalco Perú S.A a 28 MW GMD for a 40 ft SAG mill for the Toromocho project, which is scheduled to go into operation in 2012. This is not only going to be a very large GMD, but at an elevation of 4'600 m.a.s.l. (over 15'000 ft) in the Andes it will be the first GMD at this altitude. ABB delivered this year a similar 28 MW GMD for the 40 ft SAG mill of the Boszhakol project in Kazakhstan. A second supplier has delivered a 28 MW GMD for a 40' diameter mill for a large iron ore project in Australia. Furthermore, ABB is currently manufacturing the 28 MW GMD for the world's first 42 ft SAG mill. With regards to the ball mills, the largest GMDs currently in operation are the two 18.6 MW GMDs for the 27 ft ball mills at Esperanza in Chile. The world's largest delivered ball mill GMDs are the four 22 MW units for the 28 ft ball mills for the Toromocho and Boszhakol project. There are numerous GMD projects for 40 ft SAG mills in the pipeline to go into production in the near future, as well as some 42 ft SAG mill projects being planned. Furthermore, the basic GMD designs for 44 ft diameter SAG mills with a rated power of up to 36 MW are available. There is a clear trend for larger diameter mills with more powerful GMDs. This trend is driven by lower grade ore bodies and higher grinding efficiency targets in order to reduce operating costs per ton. And there is no reason to believe this trend should not continue.

Issues with GMDs

Not only the grinding efficiency counts: the reliability and availability of the complete grinding circuit is of paramount importance. About two decades ago there have been several issues with mill shells all over the world, but the main mill suppliers have obviously managed in a professional way to overcome these issues; lessons have been learned. On the other hand, until a decade ago the GMD was considered to be extremely robust. But during this last decade certain issues with GMDs from all GMD suppliers occurred, where some issues were more severe than others. There are different root causes for these issues and some of them resulted finally in serious unscheduled shutdowns and significant insurance events. But in hindsight not all failures should have ended in the way they did.

Most of the notable "insured" failures happened on relatively large mills, as the financial impact of a failure is proportional to the through-put of the mill. Hence it was not very surprising that this led to a hesitating attitude of not only the owners to select large mills (it took the industry more than a decade to make last year finally the step from 40 ft to 42 ft SAG mills), but also to a hesitating attitude of the insurance industry to insure large mills and their GMDs. At the same time as shown above, there is this clear trend for larger diameter mills and GMDs with higher power densities. In other words, an apparent conflicting situation occurred. It is obvious that if not handled correctly, this ongoing trend could potentially lead to major conflicts as it becomes difficult for the insurance companies to judge the risk and hence may result in hesitation to insure these grinding circuits.

ONE COMMON INTEREST

This conflicting situation had to be addressed properly, as it was not desirable and not acceptable for the owners, the suppliers or the insurance companies. In order to master this conflicting situation, all the involved stakeholders have to work together. For some new projects with large mills, all these stakeholders were truly interested to cooperate in order to find a way forward with large mills and GMDs acceptable for all parties. Several workshops sessions have been held with key persons from these stakeholders participating. It was soon realized that not only the mining companies themselves, but also their insurance companies and the involved equipment suppliers have one common interest: to reach the highest possible availability by avoiding or at least minimizing unscheduled shut down times. In other words: to prevent unplanned events that result in extended production stoppages or reductions in through-put of GMDs. Consequently the "Severity" and "Probability" variables in the postulated Risk formula are being addressed and minimized.

Scheduled versus Unscheduled Shutdown

If the GMD suddenly fails without any pre-warning or advance indication, then an unscheduled shutdown is unavoidable. This can easily lead to extensive unscheduled downtimes; the keywords here are "extensive" and "unscheduled". Due to an unexpected failure, the mill is from one to the next moment suddenly standing and the production is immediately affected. The operation and maintenance crew on site is totally caught by surprise and will most likely need quite some time to do a first analysis, preferably supported by specialists of the equipment supplier (e.g. via phone, remote diagnostic, on site support). Whenever the failure source is finally found, then, on the spot and under enormous pressure, a plan has to be developed to get the mill back in operation as soon as possible. The necessary repair procedures will have to be developed under stressful conditions and the required spare parts will have to be located immediately.

Instead the aim should be that any abnormality in the complete system is being detected in a very early stage before it leads to an unscheduled shutdown of the mill. When such an abnormal condition is detected, together with the equipment supplier it shall be analyzed and the corresponding risk level has to be defined. There is time to develop a plan to mitigate the risk. Maybe the mill still needs to be stopped for the risk mitigation measures, but then this can be scheduled. A scheduled shutdown is always, and under all conditions, better than an unscheduled shutdown: all the right persons, spare parts, consumables, materials with an expiry date, etc. can then be organized in advance to have them available during the scheduled shutdown. The complete work procedures can be developed under normal conditions and all the preparation work can be performed in advance when the mill is still running. All these satisfying circumstances will ensure that the downtime can not only be scheduled, but also minimized. The keywords here are "scheduled" and "minimized".

But still it is possible that for no matter what reason, out of the blue sky there is a totally unexpected failure, leading immediately to a trip of the mill and an unscheduled shutdown. Then the first priority shall be to get the mill as soon as possible back in operation, in order to limit this unexpected down time. Preferably a quick temporary repair should be performed and the complete final repair can then be performed some time later when everything is prepared. This final repair work will then be performed in a scheduled and minimized shutdown. The keywords here are again "scheduled" and "minimized".

Targets

The targets have now clearly been defined: unscheduled downtimes shall be avoided as much as possible. Obviously for new installations the complete team should endeavor for a truly impeccable GMD when starting commercial operation, followed by a comprehensive service concept. But if an unscheduled shutdown still happens, then its duration shall be kept to an absolute minimum. Risk mitigation work which requires a stoppage of the mill, shall be carried out during a scheduled shutdown with a minimized duration. In order to reach these targets, a truly comprehensive approach of the GMD is required, all the way from the design till the operation and maintenance stage.

COMPREHENSIVE GMD APPROACH

The whole concept for new grinding projects with large GMDs shall be based on following pivotal pillars:

- Design
- Professional project execution during manufacturing, transportation, storage, installation and commissioning
- Comprehensive service concept

Design

When striving for a GMD fulfilling the above described target features, the following design related topics should be addressed.

<u>Research and Development</u>

It starts at the very beginning with the research and development of the GMD. The GMD supplier shall be continuously receptive for new ideas and continuously developing new control and protection features. The reason for this is to get closer to the ultimate target to detect any abnormality in such an early stage that unscheduled shutdowns can still be prevented and the risk can be successfully mitigated. The following are only some examples with which we explain what is meant by this.

- Online partial discharge monitoring: partial discharge monitoring when the mill is in normal operation, which will give the owner an indication of the status of the stator winding insulation.
- Rotating airgap monitoring: a rotating airgap sensor installed on the rotor which will give, together with the standard installed static airgap sensors, a truly 360° overview of the rotor, stator and airgap.
- Real motor differential protection and an accurate and fast earth fault protection not only during normal operation, but also before and during the start sequence of the mill (which

is a challenge, due to the very low operation frequencies of the motor, no standard 50/60 Hz protection relay can be used)

- A sophisticated control of the gearless motor without the need of a speed and/or position encoder; in other words eliminating a potential failure source
- Rotor winding temperature monitoring

Such protection features require development and can indeed help to detect an abnormality in an early stage. Although such protection features are typically not specified (and would make the GMD less attractive from a CAPEX point of view), the GMD supplier could still offer them as an option.

Design Process

The complete design shall allow for certain safety margins, on which no compromises at all shall be tolerated. Due to the relatively low number of units, the GMD supplier should always be vigilant for global experiences from existing GMD installations. If somewhere a failure happens, then a detailed root cause analysis shall be performed and the loop to the design for new GMD projects shall be closed: a NCR (non compliance report) has to be issued and it has to be checked in detail whether or not a design change for new projects is required. This change can be a generic change or it can be specifically implemented on a project to project specifics. Naturally, also the complete installed base shall be thoroughly assessed. If a failure happens, then the lesson should be learned for the whole installed base, including the ones still in manufacture.

In the situation of a project going to inexperienced levels (such as higher elevations, larger diameter mills and/or larger power GMDs), then just scaling up the existing design can lead to undesirable risk levels. This has to be carefully analyzed, designed and reviewed. Also the opportunity of having an additional design review by an independent design team can be considered (a four eyes strategy). When making a design change in order to avoid or limit a certain potential failure source, then at all times the whole system has to be evaluated. This is because a certain design change can not only have the required effect of decreasing the risk level on one point, it could potentially at the same time increase the risk levels at other points in the system to unacceptable levels.

Design for maintenance and service

In a concentrator, conflicts could easily arise between production targets and recommended maintenance schedules. If not managed correctly, this conflict could finally lead to increased and uncontrolled risk levels. Although it must be absolutely discouraged to have such a situation, it is still beneficial to take this potential conflict into consideration in the design of the GMD. In other words, ideally the GMD would be completely maintenance free. It is needless to say that this is impossible to achieve. But still, even in the hypothetical case of having designed, manufactured, transported and installed a completely maintenance free GMD, this does not mean that it would also be inspection free. So the target is during the design phase to make the GMD as maintenance friendly and as maintenance free as possible and after being installed and commissioned, to perform regular inspections.

In addition a risk analysis of potential failures and their impact shall be available and the design shall account for possible fast repairs on site. And here the design does not mean only the “GMD design”: also the area at site around the GMD needs to be designed by taking into account the maintenance tasks and potential repair actions. Is there access to all necessary locations? Can parts be replaced if needed? No additional infrastructure is in the way (like piping, building construction, etc.)? These are only some of the questions that need to be considered during the overall plant design phase. The MTTR (Mean Time to Repair) value is an important parameter, which shall be addressed during the design. Ideally, the design should consider that all repairs, at least temporarily, could be concluded within 24 hours. For example, imagine a failed stator winding, which results immediately into an unscheduled shutdown. To repair this, the stator normally has to be shifted into the maintenance position, which takes significant time while the GMD continues to be out of operation. How difficult and time consuming it is to replace the failed winding depends on several factors such as:

- location of the failure (at top or bottom of the slot, end winding area or inside of the core)
- the selected winding system and technology
- availability of required spare parts and consumables (maybe even with an expiry date)
- availability of skilled personal on site

Finally such a stator winding failure can then easily lead to a downtime of days or more. It can also be handled differently, if designed correctly from the beginning; the failed winding could then easily be isolated and bridged, even without the need of shifting the stator. It has to be ensured that the required materials to perform this bridging are available on site and then the GMD can be temporarily repaired within a few hours. For the final repair of the failed winding, the stator will still need to be shifted into the maintenance position, but this can be done during a scheduled shutdown. Before this stator shifting, there will be more than enough time to get fully prepared to perform this final repair; well trained specialists and all the required materials can be made available in advance for the scheduled shutdown, where the duration can then be truly minimized.

Impressive technology developments during the last decade have truly opened the door for advanced remote services. A decade ago the remote connection was typically realized via modem, resulting in a relatively slow connection and a very limited amount of data transfer. Nowadays, technology enables us to transfer huge amounts of data very fast. In other words the GMD supplier can be easily flooded with data. Therefore the GMD supplier shall have developed sophisticated analyzing procedures to look for, without human intervention, for notable patterns and trends in this flood of data; again with the target in mind of detecting any abnormal condition at an early stage. In addition every GMD shall be equipped with a transient recorder, or a high-speed data logger; after an incident on the GMD, this device can accelerate the root cause analysis by providing detailed information on all the relevant signals in high resolution, starting at a time just before the incident to just after the incident. Again via the remote connection, the trouble shooting engineer on duty from the GMD supplier shall have the possibility to immediately access this high resolution information.

Manufacturing

No matter how perfect the design is, even minor flaws during the manufacturing could finally lead to failures during operation and corresponding down times. Therefore a thorough quality assurance and quality control process shall be in place, in order to monitor that the components are indeed manufactured exactly as designed. In the event that a non compliance is detected, this shall always be filed with a Non Compliance Report (NCR). It has to be analyzed whether corrective measures have to be taken or if the non-compliant component can still be used without increased risk; also this analysis and the decision shall be filed in the NCR database, allowing for traceability.

Logistics: Packing, Transport and Storage

It is not enough to have a perfect design and a faultless manufacturing. In addition, if equipment and material is not packed, transported or stored correctly, this can lead to an increased risk level during operation and eventually cause unscheduled downtime.

The packing of GMD equipment and material must fulfill the relevant transport requirements like adequate lifting possibilities, protective structure supports and for example sea freight packaging. Typically GMD shipment includes four stator partitions and additional 20 to 30 boxes that include material (like rotor poles, stator and rotor covers and stator winding completion material) and tools required for site installation.

In some cases, the GMD will be stored for a period of time prior to installation. Optional instruments like humidity sensors to measure air humidity and air temperature can be added inside of packing in order to monitor the condition of the material during transport and storage. The packing process must rely on systematic quality assurance and quality control processes, analogue to those for the manufacturing process.

Due to the massive size and weight of the GMD sub-assembly, the shipping of the GMD sub-assembly must be organized by a truly heavy load transport expert. Special attention must be paid to the availability of cranes with sufficient capacity when loading and unloading the GMD sub-assembly.

For storage conditions, the manufacturer issues detailed specifications that must be strictly followed during transport and storage. If necessary, additional equipment like dehumidifiers or space heaters can be offered as options for the packing. The target for all this is to have the GMD still in optimal conditions when the installation takes place. Failure to follow transport and storage conditions and specifications can lead to material damages that could be root causes for unscheduled downtimes during operations.

As seen above, the logistics part of a GMD delivery introduces requirements and actions that must be managed carefully.

Some means to mitigate logistics related risks are:

- Packing inspection at factory: to review content, dimensions and weight of the boxes and transport units as well as all relevant shipping documents (packing lists etc.)
- Inspection and testing of material during and after transport (for example stator winding insulation test for stator partition after sea transport)
- Analysis of transport route (tunnels, bridges, etc.: transport dimensions, transport weights, infrastructure, legal, etc.)
- Comprehensive inspection program (as defined by manufacturer) during storage time

The purpose of the above mentioned inspections and analysis is to monitor and control the GMD components during transport and storage in a way that problems can be detected as soon as possible and any required corrective actions can be promptly started.

Installation and Commissioning

We have discussed the importance of the design, manufacturing and logistics periods in order to reach the target: the highest possible availability of GMD during the operations. While mastering all the mentioned phases, another truly important and challenging stage in the GMD project is the installation and commissioning (I&C) phase. When executed correctly, I&C activities provide a solid starting point for care-free operation and maintenance phase.

The I&C period (consisting of the installation, pre-, cold and hot commissioning) at site can be described as a funnel that brings together a number of bits and pieces that were not together before, such as schedules, plans, systems, procedures, materials, interfaces and personnel from all stakeholders. Prior to GMD installation activities at site, it is possible to treat different project components (like individual installation time schedules for mill and GMD) separately. But during the GMD installation, schedules, plans, systems, procedures, materials and interfaces (to name few) from different sources must converge and fit together. For example, mill liner installation must be coordinated with the GMD installation activities and rotor pole installation requires operational mill lubrication and brake systems. Of course these site activities do not pass the funnel without thorough preparations and detailed planning.

Due to the nature of the large scale of GMD projects, with their major infrastructural challenges, it is almost unheard of that GMD I&C period runs without interruptions from the start of installation till end of the hot commissioning and handing over to customer. Interruptions for GMD site team's activities can be as long as several months. For example the first run of the GMD without any load can be three months before belt conveyors can feed the material into the mill. This means that between the first no-load run and the first run with load, there might not be a need to have a complete GMD commissioning team at site. In such cases it is very important that there is a common understanding between the team that stays at site and

GMD specialists about the operational limitation of the GMD. As long as the GMD has not been tested with full load through the whole speed range, the GMD control system limits the GMD operation to within a tested range. Since commissioning activities can be spread over a long period of time, it is very important that the cold commissioning plan and the hot commissioning plan include clear definitions of the scope of the works for each commissioning team for every commissioning step. Also special attention must be paid on passing the correct information from one team to other; for example when cold and hot commissioning is led and done by different teams.

As mentioned, the proper planning is vital for successful site execution. Some measures that contribute in reduction of I&C related risks like material damages or schedule delays are listed below:

- Site survey prior to site activities
- Pre-installation meeting
- I&C contract with clear division of work between parties
- Common installation schedule (owner, mill supplier, GMD supplier)
- Common commissioning (cold and hot) schedule (owner, mill supplier, GMD supplier)
- Risk analysis for site works
- Regular meetings during the site activities (daily site meetings and schedule updates)
- Clear escalation plan in case of problems
- Commissioning spare parts at site

Nevertheless, it can be said that one can have all possible plans, procedures and processes in place but without a skilled teams at site, it is very difficult to have successful site execution. Even if there is thorough planning in place, there is always a need for experienced site manager and site supervisors who are able to close eventual gaps and hand over tested and fully functioning GMD system to operations.

Operation and Maintenance – Comprehensive Service Concept

It goes without saying that the grinding circuit owner and operator understand their entire operations completely. For example, all bottlenecks and weak points of operations must be identified and consequences of failures must be understood. In the case of the GMD, it is recommended that the operator carries out together with the GMD supplier a formal risk analysis that covers the GMD operations, GMD maintenance activities and handling of GMD spare parts. Since no operation is exactly the same as any other, this risk analysis must be specific for the grinding line or at least for the site. The outcome of risk analysis, which should be continuously updated due to changes in processes and personnel and such, should include among other things, descriptions of hazards, their root causes, hazard effects and consequences with probabilities. Additionally, a level of risk acceptance and improvement measures should be discussed in the analysis. The risk analysis is an important part of owner's/operator's process in defining and implementing the best possible operation and maintenance strategy for his plant.

Furthermore the comprehensive GMD service concept should be built around following so-called 7-i principles:

- Implement risk analysis process for operations and maintenance that is continuously updated
- Inspect GMD on regular basis (report and record all findings)
- Identify abnormalities as early as possible
- Introduce emergency plans with temporary repairs in order to get back to production as soon as possible after failure
- Install risk mitigation and final repairs during scheduled shutdowns
- Invest in correct skills, tools, materials and spare parts and have them available
- Improve systems and processes

These principles can be followed when the comprehensive GMD service concept focuses on predictive, preventive and corrective maintenance:

Predictive Maintenance

Predictive maintenance includes early detection activities that identify and mitigate any problem before it causes unscheduled shutdown. On-line condition monitoring with real time analysis of the status of the operations or vibration measurements of stator frame are examples of predictive measures.

Preventive Maintenance

Preventive maintenance tasks are for example supplier defined maintenance activities like visual inspections and part replacements according to recommended maintenance schedule. In addition, remote periodic maintenance reports issued by GMD supplier complement site inspections and operational team's observations by providing periodic statements on the status of the GMD system and operations commented by GMD supplier's specialists. Preventive maintenance increases availability, reliability, productivity and lifetime of installed equipment and systems significantly.

Corrective Maintenance

Corrective maintenance means repairing services that focus on resolving any eventual emergency thoroughly and effectively. Telephone support (24/7 SupportLine), on-demand mobilization of service personnel and emergency part delivery are some of the corrective maintenance measures.

Target

For grinding circuit operations, the clear target is to have the GMD reliability and availability as high as possible. As already mentioned, the highest availability can be reached by avoiding or minimizing any unscheduled shutdown time. In practical terms the GMD service concept should have a clear focus on early detection of any risks or abnormalities, so that these risks can be analyzed, mitigation can be introduced in a planned manner and as a consequence unscheduled shutdowns can be minimized.

The market demand and availability of ore are the main drivers for mill operations, requiring the production to be running round the clock without any interruption. However, it is not possible to run mills continuously without any stops: eventually mechanically wearing components of the mill, especially mill liners, need periodic maintenance and replacement and for those actions, mills need to be stopped. This is another aspect that must be considered in the comprehensive GMD service concept. In order not to introduce any additional downtime, GMD preventive maintenance tasks should be designed and planned so that they can be completed either when the mill is still in operation or at the same time as the regular mechanical mill maintenance. Based on this approach, no extra shutdown time in addition to stops due to mechanical maintenance activities, is required for GMD preventive maintenance.

But even if all possible predictive and preventive measures are in place, still something unexpected could happen; due to some sort of breakdown the GMD will stop with an unscheduled shutdown. For these cases, an emergency plan should be included in the comprehensive service concept. The purpose of the emergency plan is to detail the actions on how to bring the GMD back into operation as soon as possible. Temporary "quick fix" repairs, naturally without making any compromises regarding safety and quality, should be considered to minimize immediate loss of production. Final repairs should be planned and performed during scheduled shutdowns. The emergency plan should cover all aspects needed for fixing the failure fast: first of all identification of potential failures, furthermore, repair work instructions, list of required tools, parts, materials and consumables and detailed time schedule and manpower requirements.

Paradigm Shift

The GMD supplier can design, manufacture, pack, transport, store, install and commission a system that considers all mentioned principles from avoidance of unscheduled downtime to easiness of maintenance and that includes maintenance and spare part recommendations. But ultimately it is the owner/operator who decides how to run his operations. Recently a paradigm shift has occurred and the importance and impact of a comprehensive operations and maintenance strategy by the owner/operator has been understood. It has become visible that cost reductions by not completing the regular maintenance activities do not bring any long term benefits. On the contrary, they could even lead to long term disadvantages and increased costs. Indeed there is a strong correlation between the maintenance performance and the level of production. Today the maintenance function gets the correct priority; a well maintained system does meet the production requirements.

It is recommended that the owner/operator develops the comprehensive GMD service concept for his GMD and plant together with the GMD supplier. Reasons for this recommendation are as follows. On one side, the owner/operator is the expert of his operations. He knows his overall maintenance strategy including infrastructure, processes, skills and capabilities of his own maintenance crew, maintenance and spare part budget and production requirement. On the other side, the GMD supplier is an expert on the complete GMD system with a comprehensive GMD service portfolio. The GMD supplier has the detailed knowledge of the latest GMD improvements, any possible incidents with GMDs in operations around the world and best practices. By combining these areas of expertise from the owner/operator and GMD supplier, it is possible to reach a real win-win service concept.

The GMD supplier's service portfolio includes typically a combination of basic and advance service products. Some examples of such services are listed below.

- Maintenance services e.g.
  - on-demand site support
  - extended start-up support after the commissioning
- Spare part services .e.g.
  - spare part recommendations (lists and kits)
  - site inventory audits for parts
- Remote diagnostics services e.g.
  - Telephone support that can be reached round the clock 365 days a year (24/7 SupportLine) combined with remote fault tracing (support engineer connects remotely directly to customer's GMD system in order to analyze the problem)
  - Periodic maintenance reports which inform customer periodically about the GMD system health and operational status
  - On-line condition monitoring which is continuous supervision of the GMD system health and operational status
- Training services e.g.
  - On-site maintenance training
  - Training partnerships
- Special services e.g.
  - Site specific emergency plans
  - Rapid Response Container for storage of all tools, material and equipment needed for emergency repairs
- Service agreements including
  - Combination of service products in one package
  - Lifecycle manager assigned for management of comprehensive agreements

A long-term (for example 5 years) service agreement is the recommended way to put a comprehensive service concept in place. These service agreements are jointly developed by the owner/operator and GMD supplier by selecting service products from the GMD supplier's service portfolio and taking into account site specific maintenance strategy and packaging this into a comprehensive service agreement. Benefits of the long term service agreement comparing to ad-hoc or on-call service strategy include predictable and reduced maintenance costs, improved expert support, guaranteed availability of specialists and faster emergency response.

But perhaps the most important benefit of the long term service agreement is its impact on reducing operational risks: the long term service agreement is a system in place where owner/operator and GMD supplier are committed for long term relationship where both parties benefit from shared knowledge and clear processes resulting in reduced downtime, increased availability and improved productivity of the GMDs.

INSURING LARGE GMDs

Providing insurance coverage for large mills, such as GMD's is possible, but it is, and will be in the future, an area that receives significant attention from the insurance industry. The opening discussion section on insuring the mining industry provided an overview of the mining risk engineering assessment, which provides the insurers with an understanding of how a specific site is managing the risks associated with their operations. When GMD's are employed at an operation, the risk engineering assessment will raise questions in order to evaluate key items of the GMD installation, operation history, and maintenance, including:

- Age of installation
    - If new installation, then specific information may be requested on commissioning and testing documentation, construction issues, risk assessments completed as part of start-up, etc.).
    - If an older installation, have there been or are there any planned upgrades to address potential obsolescence issues regarding GMD components.
- Configuration of the mill installation with respect to fire exposures including lubrication systems, electrical installations such as transformers, MCC's, and cycloconverter rooms, and other flammable and combustible hazards.
    - Is adequate separation (spatial distance or physical construction of fire walls) present for transformers and lubrication systems?
    - Is fire protection installed in the lubrication rooms and MCC's, cycloconverter, and control rooms?
- Mill condition monitoring and protection capabilities including:
    - Stator and rotor insulation resistance measurements
    - Continuous air gap monitoring between stator and rotor
    - Lubrication system monitoring for oil temperature, oil pressure, and flow
    - Winding temperature monitoring
    - Rotor and stator earth fault monitoring
    - Differential protection (phase current imbalance)
    - Partial discharge detection (insulation breakdown)
    - Cold/hot air temperature monitoring
    - Moisture detection and monitoring
    - Cooling water temperature and leak detection monitoring
- Mill performance metrics such as availability (note, extremely high availability may be indicative of inadequate time allotted to perform predictive and preventative maintenance / inspections).
- Maintenance agreements that may be in place with GMD manufacturer or other GMD specialist contractors/consultants.
    - Is on-site support provided for periodic inspections?
    - Is emergency response support provided (remote advice or on-site response)?
    - Does the ability exist for the manufacturer to remotely monitor / audit the performance of the mill?

- Maintenance plan – is the site maintenance plan for the mill been in line with manufacturers recommended activities, and have all activities been completed within the recommended frequency.
- Review of completed maintenance and inspection records for last inspection of the GMD and other key components of the mill.
    - Have all aspects of the maintenance/inspection tasks been completed and documented as such?
    - Have any deficiencies noted been addressed, or are plans in place to address in the near future?
- Is the site in receipt of the most recent field updates from the GMD manufacturer, including information on related faults, failures, or issues at similar installations within the industry.
    - If there have been recent issues noted within the industry on similar installation, have appropriate inspection or repairs been performed on the GMD, per the manufacturers recommendations, to mitigate potential for repeat of failure.
- Review critical spare holdings for GMD components, to determine if an adequate number of stator segments and rotor windings are held in stock.
    - What are the storage conditions of these critical spares and are they periodically reviewed and inspected to ensure they are still in useable conditions.
- Has the site established a formalized "Business Continuity Plan" (BCP), to cover potential loss scenarios involving the GMD mill?

If significant deficiencies are identified during the review of the above items, then questions of insurability of that specific mill may arise. However, if the site is able to demonstrate that the above items are well managed, with no significant issues relating to the performance of the required maintenance activities, and any GMD issues that may be present are being managed in a prudent manner, then the risk engineers and insurance underwriters will likely be equipped with the information they need in order to have confidence in providing coverage to the mining companies that utilize GMD's in their processes.

The remaining concern that the mining insurers have with respect to GMD's is the continued growth in size of the mills. The primary concern related to the mills growing larger is that there is no ability to conduct long-term R&D testing on the larger mills. They are designed, manufactured, and installed in a mining operation that has made a decision to employ new technology related to the increase in size of the mill. The questions and uncertainties related to the increase in size of the mills are difficult to answer and provide confidence to an insurance underwriter, as the increase in size has not been proven over a long period of testing.

The answer on whether an increased mill size is "insurable", and if insured, what the structure of the coverage will be, is left to the specific companies that choose to push the technology to the next level having detailed discussions with their insurance underwriters, and with the GMD manufacturer providing technical support as required. The context of these discussions should provide information to the underwriter on actions that have been or will be taken to understand and control the increased risks associated with the increased mill size. Specifically, a focused hazard assessment and risk analysis should be conducted on the new installation. Additionally, the commitment to mill spares should be identified well in advance, and should consider increasing the spare stock holdings, compared to a smaller GMD, as the performance of the larger GMD mill is unproven. An increased spares holding provides mitigation for unforeseen failures, by significantly reducing the time required to repair (compared to not holding adequate spares).

CONCLUSIONS

It has to be acknowledged that a guarantee for absolutely trouble free operation for many years is not certain. This fact combined with the knowledge that the availability of the mill and GMD is paramount leads us to the only possible and acceptable approach. The mindset of all stakeholders must be continuously, all the way from the design till commissioning and also during operation, focused on trying to detect any abnormality in an early stage; then there is plenty of time to develop together a plan to mitigate the risk and to avoid, or at least to minimize, unscheduled shutdown times. With the comprehensive mindset and approach described in this paper both the “Severity” and the “Probability” aspects are being addressed and minimized, consequently reducing the corresponding risk level.

The issue of the insurability of large mills, where the severity of a loss is significant, is not black or white, nor is the answer a simple “yes” or “no”. The actions taken by all parties involved to gain the fullest understanding of the risks related to GMD installations, and to mitigate these risk through the application of effective risk management practices will improve the likelihood that the insurance underwriters will continue to remain confident in providing coverage.

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NOMENCLATURE

R = Risk = Assessed loss potential
S = Severity of the effect
P = Probability of occurrence

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