Power Quality in Metals and Mining Facilities

In a mining operation, the facility's infrastructure heavily relies on electric power. Yet no other industry places greater demands on electrical power distribution systems than mining. Harsh conditions, non-linear loads, extensive use of long cables for mobile equipment, complex grounding, and the adoption of ever larger machinery with higher power requirements all challenge the reliability of the power that mines depend on to keep operations running 24/7, 365 days a year.

This whitepaper will address how to improve power reliability in mines and reduce the total cost of operations related to power quality issues. It covers the four common types of power quality disturbances mines experience and provides mitigation tactics that enhance safety, reliability, productivity, and cost efficiency.

Power quality is critical in mining since even short interruptions can lead to equipment damage and production losses costing hundreds of thousands of dollars per hour. Besides downtime, poor power quality can pose safety hazards to workers, especially those underground or in confined spaces. Without reliable power, a mine's ventilation and lighting systems may fail or malfunction, making it difficult to see or breathe while combustible gases and dusts climb to dangerous levels.

Mining Power Systems

Mines generate electric power from a variety of sources, sometimes resulting in a patchwork system. When AC grid access first became available in the 1890s, mine operators began purchasing much of their electrical power from utility plants and it remains the primary source today. High voltage DC power is also used, mainly for electric rope shovels, uninterruptible power supplies (UPS), and emergency systems. It is supplied by AC-to-DC conversion or by onsite DC microgrids. In addition, fuel-driven generator sets (gensets) are commonly used, as are gas fired boilers and renewable energy sources.

Power systems in mining operations vary greatly but in general, they will follow a basic design: high voltage power coming off the electric grid feeds high voltage transformers that supply a main substation. In turn, the main substation distributes energy to multiple secondary substations as well as directly to the mine's largest motor loads. Secondary substations supply power to medium voltage loads and to medium voltage/low voltage transformers that connect to motor control centers. Mines consume tremendous amounts of power ranging up to 120 megawatts per 100,000 tons of mined product each day. ①

When it comes to sourcing power, utilities offer mine operators two major advantages over gensets. First, they do not require the storage and transportation of flammable fuels over many miles of harsh road and terrain. Second, utilities can respond more effectively to load variations beyond the capacity of local generation options which have less capacity and are prone to significant fluctuations in voltage and frequency. Incidences of voltage variation and power outages are more frequent in the mining industry than in most other industries, largely because mines are typically located in remote areas far away from population centers and existing electrical grids. Transmitting electricity over long distances to a mine can result in power loss, voltage drop, interference, and weather-related outages from high winds, lightning strikes, or ice storms. Utility supply switching (breakers, contactors, or taps) can also give rise to damaging voltage surges.

Internal Power Disturbances

While the first inclination of some mine operators may be to blame the utility for power quality issues, that view is frequently inaccurate. It's far more common that power quality problems arise from dynamic conditions within the mining facility, manifesting in the form of overvoltage swells, undervoltage sags, harmonic distortion, or total power interruption.

As preface to evaluating power quality disruptions, consider the variety of electrical equipment and the different types of power loads in mines. Understanding the diverse nature and complexity of mining equipment sheds light on why power quality problems are so common. In underground mines, the power system must supply locomotives, drills, shearers, crushers, loading machines, belt and shuttle conveyors, roof bolting machines, hoists, chillers, ventilation systems, and pumps. In surface mining, there are power hungry rope shovels, drills, and excavators. Extracted materials transported to processing plants encounter large crushers, grinding rolls, semi-autogenous grinding (SAG) and ball mills, and exhaust and dryer combustion fans.

Regardless of layout or equipment loads, all mine power systems face the challenges of poor power quality. The costly consequences of power quality disturbances range across operational interruptions, lost data, damaged equipment, energy inefficiency, utility fines, reduced productivity, and possibly worker safety. Due to a mine power system's complexity, a single power quality solution is rarely adequate to ensure reliable power. The variability of power disturbances therefore requires a multi-tiered approach that often starts by identifying power-offending devices, such as drives, motors, and pumps.

Over the years, the mining industry has begun to implement more technological innovations within their processes. With digital transformation now in process, the deployment of sophisticated electronics sensitive to power quality disturbances may require protection using tracking filters and surge protective devices. It's critical that mining operators specify high quality power conversion products, including K-Factor and Drive Isolation Transformers. Last, but not least, all control panel points should employ surge protection devices. ②

Emerson's Solution
Mining operators need a power quality partner with extensive experience and global reach in delivering innovative power solutions to optimize performance, improve cost efficiencies, enhance safety, and increase equipment longevity. For over 100 years, SolaHD total power quality solutions by Emerson have neutralized the damaging effects caused by power disturbances from service entrances to load points to communications networks, making SolaHD power quality (PQ) devices indispensable to today's industries. Emerson merges superior SolaHD products with world-class customer service and support. Count on us for best in class SolaHD brand power supplies, filter and surge protection, data/signal surge protection, tower and rackmount UPS, power conditioners, automation transformers, and distribution transformers – all backed by award-winning expertise and global support. To further improve efficiency and productivity, Emerson offers SolaHD high performance power supplies and UPS with communication capability allowing mining operators the ability to monitor critical power devices remotely across the network providing real time diagnostic and maintenance information.

Four Common Power Quality Disturbances in Mines

1. Voltage Sags and Undervoltage

Voltage sags and extended undervoltage conditions are the most common power quality disturbances in underground longwall mining. They occur when a large increase in load current stresses the electrical supply system, causing the supply voltage to drop below levels at which equipment is designed to operate. Voltage sag, as defined by IEEE, is a reduction in voltage for a short time. The voltage reduction magnitude is between 10% and 90% of the normal root mean square (RMS) voltage at 60 Hz. The duration of a voltage sag event, by definition, is less than 1 min and more than 8 msec, or a half cycle of 60-Hz electrical power. ③ Undervoltage events are similar to voltage sags but extend over one minute.

In mines, the underlying causes of sags and undervoltage may include the start-up of high-power motors, transformer inrush, ground faults, short circuits, or tripping and reclosing circuit breakers. Contributing factors may include the long cables commonly used for mobile equipment, and the incorrect specification of transformers.

Both sags and undervoltage may cause nuisance tripping of breakers, equipment malfunction and shutdown, or premature equipment failure. Operation at reduced voltage will increase heating effects at high-resistance connections, elevating the risk of combustion or explosion in classified areas. Signs of these issues include dimmed or flickering lights, poorly operating HVAC units, and motors running hot. PLCs, automation control systems, and computers may lock up or power down, resulting in lost data, increased production costs, and a greater probability of equipment failure.

Emerson's Solution
SolaHD industrial-grade sag and undervoltage protection devices by Emerson isolate and correct the incoming line to match the voltage requirements of connected equipment when the supply is disrupted. Our SolaHD UPS systems prevent power interruptions by seamlessly switching to back-up battery power the instant a voltage irregularity is detected. Plus many offer a robust design featuring a wide temperature range and the convenience of DIN-Rail mounting. Rugged IP67 rated power supplies, like the SolaHD SCP-X Series, feature sag immunity and can be safely mounted on mining machines and conveyors without an enclosure to supply 100 to 240 watts of power. Other field-proven solutions are SolaHD hardwired and portable single-phase power conditioners which provide superior voltage regulation, noise filtering, and surge suppression. Our SolaHD SOLATRON Series three-phase conditioners have set the industry standard for protecting equipment against voltage sags and spikes, switching transients, induced surges, and lightning strikes.

2. Overvoltage/Swells

Overvoltage and voltage swells, can also be known as transients, spikes, or impulses. The control of overvoltages is essential. An overvoltage condition may occur by accidental contact of equipment with a higher voltage system, or from transient phenomena due to lightning strikes, intermittent ground faults, autotransformer connections, or switching surges. The maximum ratings for cable insulation, transformer windings, relay contactors, and so forth may be temporarily exceeded in these cases. This does not usually result in an immediate breakdown of equipment,

but component parts of the electrical system are successively overstressed and weakened by repeated exposure. This leads to premature failures, reduced component life, and mysterious "nuisance trips," which can occur without apparent reason. ④

A consequence of overvoltage is insulation degradation. Deteriorating insulation jeopardizes the safe operation of the entire mine power system. Weakened or failed insulation can serve as a catalyst for electric faults, power outages, fires, and the explosion of methane and coal dust. Insulation is designed for its safe maximum applied voltage along with a transient overvoltage rating indicating the peak voltage it can withstand. If regularly subjected to above peak voltage, insulation will progressively weaken until it fails, resulting in a line-to-ground or line-to-line fault. Weakened insulation in a portable mining cable represents a safety hazard since the insulation appears to be functional when a lethal potential may exist on its surface.

Emerson's Solution
Emerson's portfolio of SolaHD Surge Protective Devices focuses on limiting high voltage spikes to a level suited for the efficient, reliable, and safe operation of connected electrical and electronic equipment. As part of our multi-level power protection, these SolaHD devices can be placed in parallel with the line and serve as clamping mechanisms for high-energy impulses. They can be installed safely at the mine's service entrance, and within its distribution panels, critical branch panels, and key point-of-use locations. Choose from one of the industry's widest arrays of industrial surge protection solutions with several models featuring continuous Active Tracking technology which reduces impulses which would normally go untouched by standard, parallel clamping devices.

Surge Protection Devices

3. Harmonics

Harmonics refer to voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate. Harmonics combine with the fundamental voltage or current and produce waveform distortion. Harmonic distortion exists due to the nonlinear characteristics of devices — such as Variable Speed Drives (VSD) — and loads on the power system ④. Harmonics can lead to increased heating in equipment and conductors, misfiring of VSDs, and torque pulsations in motors. Other symptoms of harmonic distortion in a mining power system are interference in the mine's communication system, flickering lights, tripped breakers, and even loosened electrical connections.

The vast majority of the loads in a mine are electric motors, most of which today feature non-linear VSDs, making VSDs the main source of harmonics in a mining operation. Standard 3-phase power VSDs have a full wave rectifier that improves motor efficiency but that generates considerable harmonics.

Emerson's Solution
SolaHD harmonic mitigation devices by Emerson help mines avoid disturbances to the power system, therefore preventing premature failure of electrical equipment and ensuring the mine meets the utility's grid code requirements. They can help save money by right-sizing transformers, circuit breakers, and cables for the application and by reducing power losses. In particular, our SolaHD drive isolation transformer is designed for Silicon Control Rectifier (SCR) variable speed motor drive applications common in mining by being specially engineered to handle the drive's mechanical stresses, voltage demands, and harmonics. Magnetic isolation minimizes load disturbances caused by the SCR drive. Standard designs are delta primary and wye secondary to match the common power sources required in most three-phase rectifier circuits. For variable frequency drive (VFD) applications, we recommend using SolaHD K-Factor transformers to minimize load disturbances.

4. Total Power Interruption

In remote areas of the world, local utility grids may struggle with the capacity to reliably support a power-hungry mine. Weather can wreak havoc on long suspended power lines supplying a mine. Gensets can fail, as can microgrids, leaving a mine in the dark.

In the event of a total power disruption all mining production comes to a halt. Safety standards require emergency diesel generators to be on-site to supply power to critical loads in case of blackouts, ensuring that mine workers can safely evacuate the mine.

Electrical equipment is another story. If left unprotected, the lifespan for even the most rugged machinery will be shortened as the result of a sudden power interruption. Blackouts are especially devastating to devices where normal shut down sequences are critical. Sudden power loss for computer-based equipment, such PLCs, automation systems, and industrial robots can result in corrupt files, lost data, and possible damage to the operating systems. When this type of equipment is brought back online, the operating system may fail to boot, or critical operational data may be lost. Furthermore, the physical lifespan of the equipment can be reduced by frequent power losses.

Emerson's Solution
SolaHD single-phase industrial UPS are essential to protect mining operations controls and critical loads. In the event of a brief or extended power failure, they will provide operational continuity and safe shutdown, therefore preventing damage to electronics and loss of data. Advanced voltage regulation allows SolaHD UPS to supply clean power to the load while conserving battery life, even during abnormal input voltage conditions.

Summary

Applying a multi-tier power quality and protection strategy has proven to lower mining costs, minimize hazards, and extend equipment longevity, helping to ensure that operations remain profitable and sustainable over time. Mining equipment has greater power requirements than ever before. These increased and varied loads have come at the same time as the adoption of sensitive electronics in mines for automation. The increased number of devices drawing power from the utility grid has led to greater dependency on the level of power quality required in today's highly competitive, efficiency-driven mining industry.

Emerson's Solution
Count on Emerson for best in class SolaHD brand power supplies, filter and surge protection, data/signal surge protection, tower and rackmount UPS, power conditioners, automation transformers, and distribution transformers – all backed by award-winning expertise and global support. SolaHD power quality solutions stabilize, control, and manage the unpredictable power that modern mines need from their service entrances through branch distribution to points of use throughout underground and surface operations.

Footnotes

1. Power Quality Issues of Distorted and Weak Distribution Networks in Mining Industry: A Review, Jalil Yaghoobi, Ahmad Abdullah, Dinesh Kumar, Firuz Zare, and Hamid Soltani, November 18, 2019

2. Mine Power Systems, Lloyd A. Morley, January 1990

3. Voltage sags and what to do about them, Jack Smith, August 2002

4. IEEE Std 1159-1995(R2001) IEEE Recommended Practice for Monitoring Electric Power Quality, August 2019

United States (Headquarters)
Appleton Grp LLC
9377 W. Higgins Road
Rosemont, IL 60018
United States
T +1 800 621 1506

Canada
EGS Electrical Group Canada Ltd.
99 Union Street
Elmira ON, N3B 3L7
Canada
T +1 888 765 2226

Europe
ATX SAS
Espace Industriel Nord
35, rue André Durouchez,
CS 98017
80084 Amiens Cedex 2, France
T +33 3 2254 1390

Latin America
EGS Comercializadora Mexico
S de RL de CV
Calle 10 N°145 Piso 3
Col. San Pedro de los Pinos
Del. Álvaro Obregon
Ciudad de México. 01180
T +52 55 5809 5049

Australia Sales Office
Bayswater, Victoria
T +61 3 9721 0387

Korea Sales Office
Seoul
T +82 2 3483 1555

China Sales Office
Shanghai
T +86 21 3338 7000

Chile Sales Office
Las Condes
T +56 2928 4819

India Sales Office
Chennai
T +91 44 3919 7300

Asia Pacific
EGS Private Ltd.
Block 4008, Ang Mo Kio Ave 10,
#04-16 TechPlace 1,
Singapore 569625
T +65 6556 1100

Jebel Ali- Dubai Office
Emerson, Building A
Appleton Group
Jebel Ali Free Zone- South
T +971 4 811 81 00

Middle East Sales Office
Dammam, Saudi Arabia
T +966 13 510 3702