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An Electrical Outlook of a Mining Concentrate Plant

Namita Rawat[1], Pankaj Kumar[2],Mili Mohapatra[3]

Department of Electrical Engineering, Fluor Daniel India Pvt Ltd, Gurgaon, India[1]

Department of Electrical Engineering, Fluor Daniel India Pvt Ltd, Gurgaon, India [2]

Department of Electrical Engineering, Fluor Daniel India Pvt Ltd, Gurgaon, India [3]

ABSTRACT:This paper highlights general Electrical power reticulation philosophy of a typical concentrator plant, typical electrical equipment that are used and other related technical aspects which must be taken care of by electrical engineers while designing a typical mining and/or concentrate plant.

KEYWORDS: Power reticulation, Concentrate plants, Prefabricated substations, Kiosk, Gearless motor drives, Multidrive VSD systems, Grounding.

I.INTRODUCTION

Metals and metal-based products have been an integral part of our lives since pre-historic times. In the beginning, humans were hunter-gatherers and later transitioned to farming as it offered a more efficient way to get food. Farming is considered to be the second major discovery of mankind after discovery of fire. The next important discovery was that of metals, beginning from bronze followed by gold, iron and copper, etc., extracted from metal ores naturally found in abundance beneath the Earth’s surface. Consequently, metal tools replaced earlier stone implements, and struggle for survival became much easier. Since then, if we look around we find that metals have been indispensable part of man for not only simple household tools, utensils and jewelry, but also for weaponry, transportation, machinery, etc. Copper, in particular, has been widely used for utensils in India. It is believed that water stored in copper pitchers is healthy to drink due to antimicrobial properties of copper. Copper has now found extensive use in electric wiring systems.

Metals cannot be grown and can only be mined beneath the surface of Earth. Mining of metals require big and complex machines, special tools, human skills, and most of all, large investments. For concentrate projects, yield of pure metal is generally a small percentage of total volume of ore processed. In most cases copper ores contain between 0.6 and 1 per cent of copper. For gold the yield is even lower, a ton of ore usually contains between 3 and 6 grams of metal.

Therefore, to achieve economy of scales in mining industry, big machines are utilized to give good returns on investments. Example of big machines can be grinding mills, Crushers, huge mining hoists, dragline excavators, transfer conveyers and pumps.

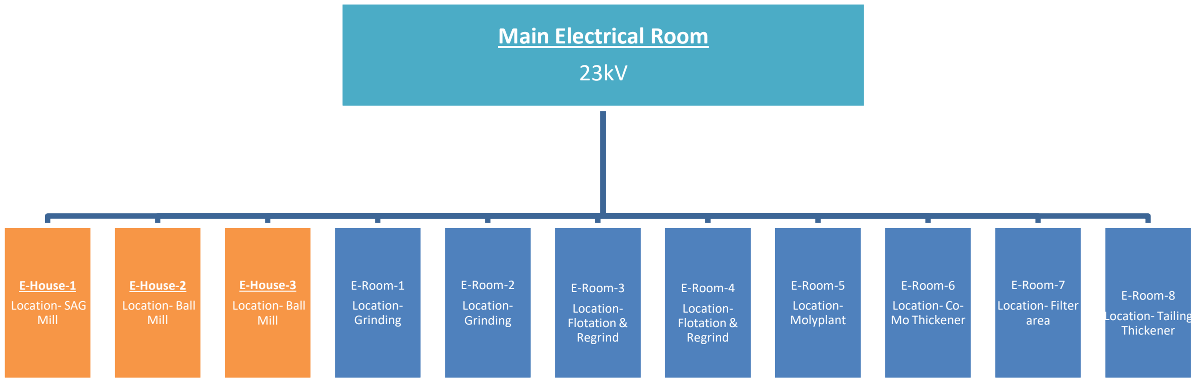
II.POWER RETICULATION PHILOSOPHY

The power system for mines is becoming more and more complex, due to higher load requirement and overall increase in size of equipment such as grinding mills, crushers, huge mine hoists, transfer belts, cyclone feed pumps, etc. There is also use of large moving equipment which include cranes, dumpers, excavators, etc.

Maximum power demand for a concentrate plant of the throughput of 95000 ktpd (kilo tons per day) can be in the order of 120 MW with the dominant power demand coming from the grinding mills (sag and ball mills), crushers, drag lines.

Most concentrate plants are located in remote areas where power supply or network conditions are less than adequate. Concentrate plants could be located on rocky terrains, where it is difficult and costly to excavate. Therefore, it is economical to reticulate the power either by overhead power lines or above grade cables rather than underground cabling system.

Generally there is one substation planned for each process area. Substations are to be located as close as it may be practical to the loads. Hence there are multiple substations for each process like crushing, grinding, flotation, thickeners, filters, etc. Locations of the substations are selected in such a way that they are away from dust or contamination zone like stockpiles.



E-Houses are by Gearless Motor Drive supplier
Prefabricated E-Rooms by Electrical vendor

Fig 1- Power Reticulation Block Diagram of a typical Copper Concentrator plant from Chile region

The load requirement in Concentrate plants demands speed variation. Almost all relevant process drives today are adjustable speed drives which include sag mill drives, ball mill drives, high pressure grinding rolls, cyclone feed pumps, primary crushers, etc. Fixed speed drives are limited to small loads. The nonlinear loads account for around 70-80% of the total installed power. This results in 70 to 90MW of nonlinear loads from a typical 120MW of installed power. Hence it becomes important to analyze harmonics of the system. The harmonic levels are required to be maintained at the Point of Common Coupling (PCC) level.

Power distribution equipment used in concentrate plants can be stationary as well as mobile and can be subjected to dust, moisture, vibrations and, in some cases, seismic activities too.

Some of the Power supply and reticulation items included in a typical mining concentrate plant are as following.

- Prefabricated substations
- Kiosks
- Gearless motor drives
- Multi-drive VSDs
- Grounding system design

III.PREFABRICATED SUBSTATIONS

With the lack of existing infrastructure, scarcity of building materials and unavailability of high skilled labour in the remote regions, where the mining concentrator plants are located, scope of electrical substations are generally planned around prefabricated building concept worldwide. Some benefits of the prefabricated substations are that it helps to reduce the number of site based contractors and workforce during construction and hence site construction costs and construction time is reduced. Additionally, prefabricated concept de-risks the project schedule.

A prefabricated substation is a compact modularized pre-assembled, prewired steel structured building, complete with lighting and small power system, fire alarm and fire fighting system, supported by Very Early Smoke Detection Apparatus (Vesda) system, Heating, Ventilation, Air Conditioning (HVAC) and telecom system in place at the site.

Execution of these prefabricated substations can be in following two ways;

Option-1: Lump sum basis on single vendor as Substation Package along with all electrical panels.

Option-2: Modular Building along with building related facilities, eg., lighting, small power, HVAC etc. in fabricators scope, where as other major Electrical items, eg., switchgear, VFD, UPS, lighting transformer, instrument & telecom panels, etc., maybe issued by the Company and/or Contractor as free issue material.

Though there are many advantages of prefabricated buildings, but design and engineering has various challenges with respect to approach, growth factor, detailing of design and future uncertainties. It is important to consider following before an engineer approaches for a prefabricated concept:-

- Substation equipment layout needs to be finalized at the time when detail engineering is not yet done and final inputs from other disciplines (Mechanical including package information, Instrumentation, Telecom, fire fighting and safety) are not fully received. In some cases, purchase orders are not placed and hence equipment dimensions are not available. Hence close coordination with vendors, sub-vendors, growth allowance become important factors.

- Cable routing for substations needs to be finalized when electrical load schedule is not final and cable schedule is not in good shape. Sometimes change management becomes difficult and it is important to consider growth allowance that needs to be considered in the initial phase.

- Equipment layout is driven by the module transportation envelope. The module dimensions are dependent on logistics for that region. While working on the substation overall dimensions, due consideration should be given to transportation limitation. All the buildings should be considered to be divided into sub-assemblies to meet the shipping envelope. Hence before freezing equipment layout, it becomes important to know in advance about the transportation limitations.

- As the cost of the modular building is higher in comparison with the stick-built building, an optimized layout is followed keeping "No" extra spaces. Height of the buildings is also optimized to reduce cost and facilitate sea transport.

Fig 2- A prefabricated building from Africa based project

IV. KIOSKS OR COMPACT (PACKAGE) SUBSTATIONS

Some of the areas of a concentrate plant are far off from the main process areas, examples camp service, administration block, mine services facilities and pond areas. In these areas, the power could be supplied through kiosk or compact substations.

Kiosk substations house an MV board, step down transformer and Low Voltage (LV) switchboard. They are in general covered by a roof which can be removed to gain access to the equipment for maintenance or repair work and when completely assembled with the doors closed. Ventilation can be by natural air circulation.

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Transformer ratings for these kiosks range from 200kVA to 3MVA.

Fig 3- A compact substation or kiosk

V.GEARLESS MOTOR DRIVES (GMD)

A mine typically handles and processes 95,000 tons to 2,40, 000 tons of ore per day. The ore needs to be crushed and milled to convert it into powdery form, before it can be sent for further processing.

In concentrate plants, for economy of scales, higher capacity machines are required, to achieve a good return on investment. Usually the plant capacities are designed on the largest machines, which are grinding mills- sag and balls mills.

Sag and ball mills are one of the most critical areas of a Concentrator plant, as they handle the largest ores. Typical power requirement of these sag and ball mill can vary from 10 MW to 30MW. Mills can be driven by different configurations of drive system, single pinion, double pinion or GMD. Gearless motor drive (GMD) becomes economical for capacities higher than 10MW.

Fig 4- Sag Mill with Gearless motor drive

The Gearless Mill Drive is a variable speed drive designed for an optimal speed adoption of the mill to perfectly match the changing process requirements. The drive system has a motor wrapped around the mill like a ring. The rotor poles are flanged directly onto the mill body, and hence the rotor becomes an integral part of the mill. There are no rotating mechanical components at all, no gearboxes, no girth gear, no pinions and even no motor bearings are required. The torque forces to grind the ore are transferred to the mill contact- free via the magnetic field of the ring motor and any mechanical wear is eliminated. Major suppliers of Gearless Mill Drives are Siemens and ABB. These are more than a motor and a drive. It is a fully automated and integrated drive system for grinding applications and generally comprises of the following components:-

- Stator in multiple sections

- Pre-assembled containerized electrical house for operation of gearless drive motor system consisting of:
  - Cycloconverters with their water cooling system and dedicated fast controller
  - Exciter rectifier
  - Low voltage MCC for the mill and PDS auxiliaries
  - Auxiliaries PLC
  - UPS
  - Main converter and exciter transformers protection panel
  - High speed transient data recorder
  - SAG mill and PDS diagnostic aid and management information including video display monitoring, supervision, data logger, and troubleshooting system
  - Communication cabinet
  - E-house auxiliary equipment and systems such as normal and emergency lighting, redundant air conditioning system, fire detection and extinguishing system, etc

- Mineral oil immersed converter transformers suitable for the main power supply of the SAG mill motor gearless drive system

- Mill drive motor Local Control Panel (LCP) to provide control for the drive and lube system from a location on the SAG/ Ball mill operation floor.

Though GMDs are standard vendor design, it is important for an engineer to consider following:-

- Conduct Harmonic filter and power compensation study. This would help in proposing harmonic filtering and power factor compensation equipment for the whole plant. The harmonic study calculates, based on the final plant network data and structure, the voltage distortion and current harmonics generated by the cycloconverter. The Harmonic Study will indicate whether harmonic filters are required to keep harmonic distortion below the specified limits. If Power Factor Correction is required, its' design must be coordinated with the harmonic filter equipment to avoid electrical resonances. Therefore Power Factor Correction Equipment can only be defined by the Harmonic Study. It is essential and also cost effective to combine Power Factor Compensation and Harmonic Filtering into a single piece of equipment.

- All special kind of cables are generally recommended by the GMD suppliers which run between
  - Cycloconverter transformer to cycloconverter
  - Cycloconverter to motor stator
  - Excitation transformer to excitation rectifier
  - Excitation rectifier to motor rotor

  Because of the lower bending radius during installation, generally high flexible cables are required.

VII. MULTIDRIVE VSDs

Design of mining concentrate plant utilizes gravity for ore processing and transportation. Examples could be overland conveyors system or flotation process. Overland conveyors can have uphill and downhill sections of many kilometers. The downhill application can use regenerative multi-drive VSD system where the drive provides braking to the conveyor and breaking energy is supplied back to the Electrical network.

The multi-drives principle is based on common DC bus arrangement, enabling single power entry and common braking resources for several drives. There are several possibilities on the supply side starting from a simple diode supply unit up to highly sophisticated IGBT supply units. Similar to a traditional MCC in concept, Multi drive unit systems utilise

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large active front end converters to supply a common DC bus arrangement on which all of the individual output converters draw power from.

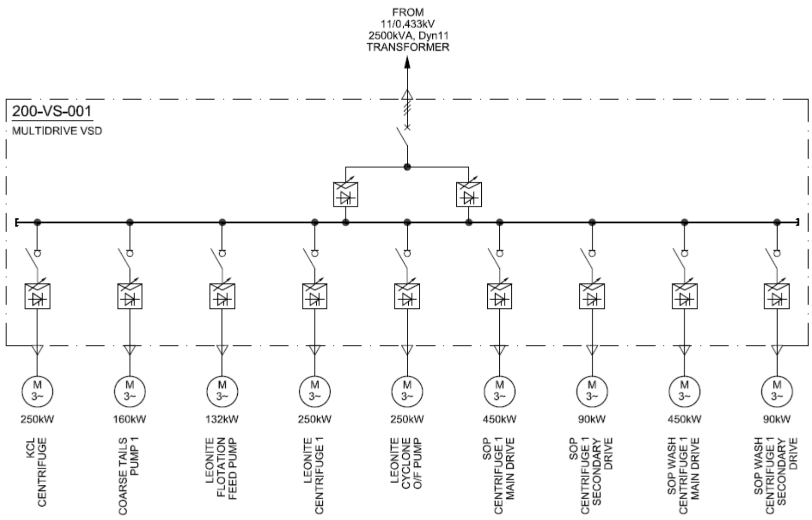

Fig 5- A conceptual single line of a typ. Multidrive system for Potash based project in Africa.

Multidrivesare used on those systems where regenerative energy is present from braking or overhauling due to the load. There are benefits and opportunities in the use of multi-drives for energy savings, increased reliability and reduced space requirement.

If the motoring load requirement is more than the braking/ regenerating load, then regenerative energy may not be required to be sent back to the grid. If it is necessary to return excess regenerative energy to the grid this is where line regeneration comes into play.

In Concentrator plants, larger conveyor systems can be driven by several motors ranging from hundreds of kilowatts to several megawatts, depending on the Conveyor profiles and downhill applications . For application of multidrive system, it is important for the engineer to be aware of the amount of regenerative energy present on any given application. This will help in selecting the components and setup for the system.

VIII. GROUNDING REQUIREMENTS

Soil having a low resistivity is good for designing the grounding system. Concentrator plants are generally located where the terrain is in general rocky and the moisture content in the soil is very low resulting in high soil resistivity. Soil resistivity of a rocky terrain varies with different layers. It is very high in the top layers and reduces as we go down. The area available for grounding system is also limited. Under such limited area and high resistivity soil conditions, it becomes quite difficult to design grounding system with low grounding resistance and safe touch and step potentials according to IEEE requirement.

In Chile Antafogasta region, which is a hub of copper concentrate plants typical soil resistivity of higher layers is found to be varying between between 3,036 and 14,402 Ω-m and lower layers have values between 913 and 1,506 Ω-m. In geographical areas like Eritria, Africa, some of the mining plants are sitting on Anhydrites, which is essentially like a rock and the top level soil resistivity could range in scale of around 10^4 Ω-m.

Soil conductive enhancement like bentonite are cost effective ways to overcome high resistivity soil. These materials are ideal for use in areas with high resistivity soil including rocky earth, mountain tops and sandy soil. Some of the products in dose of 21kg per linear meter along the grounding grid can reduce soil resistivity up to 120 times.

Hence requirement of special chemical grounding enhancement product or deep bore grounding has to be checked during grounding system design for Concentrate plants. In case if excavation is costly in the selected project site, a trade off could be made between no. of grounding rods and the dosage of grounding material per linear meter.

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IX. SUMMARY

Power systems in Mining Concentrate plants are complex and cannot be handled in a similar way like petrochemical or power plants. Electrical distribution system and the major electrical equipment are different because of fluctuating nature of ores, volume of ores present, remote locations, soil conditions, etc. Hence, it is imperative to understand the power reticulation philosophy and the typical equipments which are required for a Concentrate plant.

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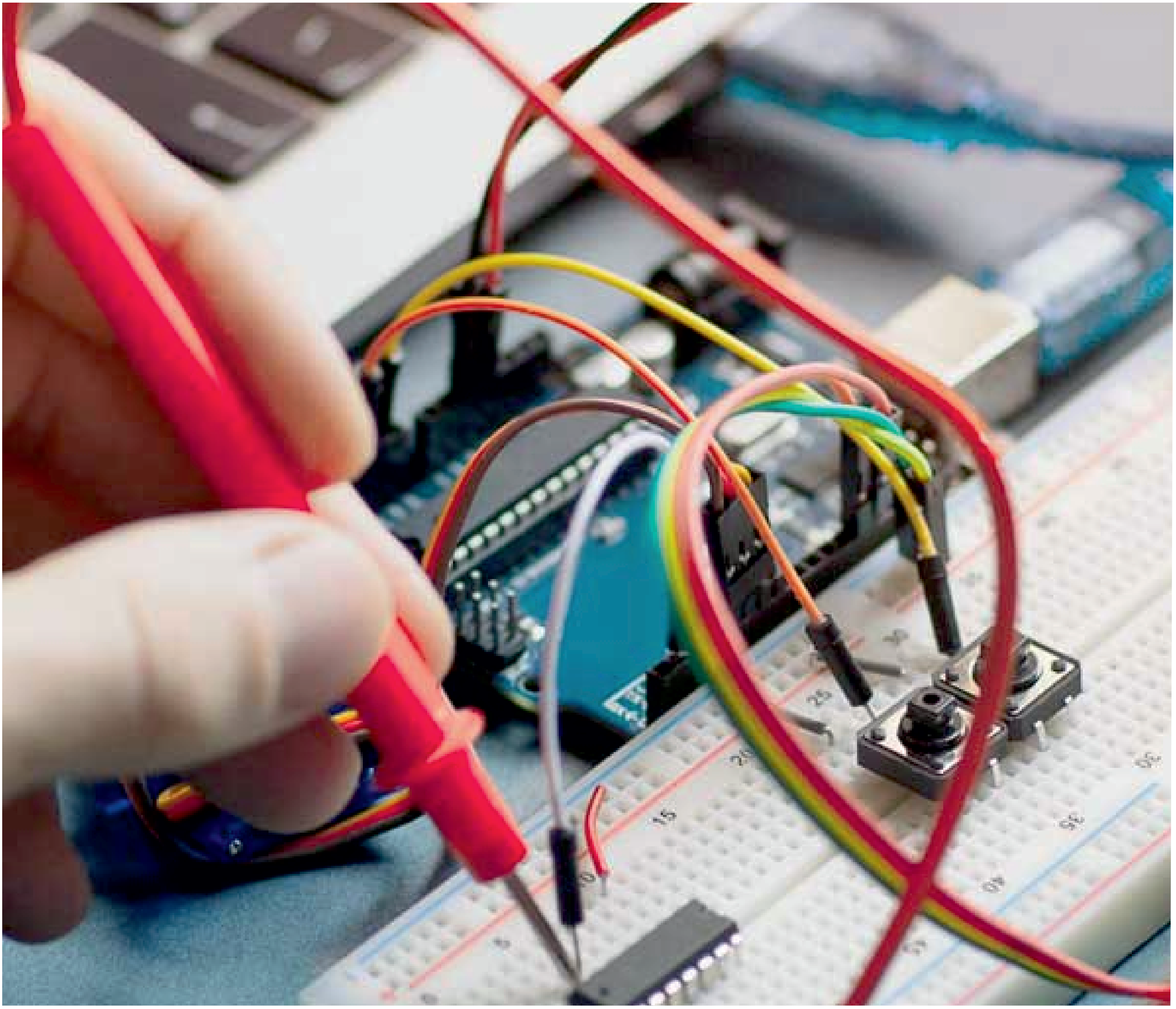

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