

Enhancing Energy Efficiency in Alumina Refineries through Motor Underload Current Monitoring

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Abstract

Electric motors are indispensable in alumina Refineries, consuming a significant portion, typically 70 % or more, of the total electricity. Despite various energy-saving initiatives like the use of Variable Frequency Drives (VFDs), energy efficient motors, power factor improvements, etc., there is still room for improvement. The operational hours of small and unmonitored motors remain largely unaddressed which ultimately increases the specific energy. Surprisingly the number and utilization of small motors (15 to 37 kW) is high in alumina refinery, especially those used for sump pit cleaning purposes. This type of area is typically controlled manually and not monitored on a regular basis which ultimately increases the overall specific energy consumption of the plant. Traditional pit level controllers, such as float and capacitance sensors, installed to optimize sump pump operation, often fail due to sedimented solids because of the nature of the process slurry. Consequently, the associated energy consumption increases. Monitoring motor load and underload currents can play crucial role in controlling operational hours. In our research, we have successfully utilized motor underload current monitoring to reduce more than 50% pump runtime, resulting in substantial energy savings by 70 kW to 80 kW per day per pump within the alumina refinery, thereby contributing to a carbon footprint reduction.

Keywords: Alumina Refinery, Energy Optimization, Motors, Underload Current.

1. Introduction

Alumina refining turns bauxite into alumina using the Bayer process, a reversible chemical reaction. First, bauxite is cleaned, crushed into powder, and then dissolved in caustic soda (sodium hydroxide) at high temperature and pressure. It takes about four tons of bauxite to make one ton of alumina, and roughly two tons of alumina to produce one ton of aluminum.

The mixture of bauxite and caustic undergoes digestion in digester vessels under high temperature and pressure to dissolve the aluminum hydroxide from the bauxite. The resulting solution is then cooled in flash tanks. Next, in the precipitation step, aluminum hydroxide crystals are recovered from the caustic solution through mechanical stirring in open tanks.

Finally, the precipitated material undergoes calcination, where it is washed and dried at temperatures exceeding 1 000 °C. This process transforms it into dry, white anhydrous aluminum oxide powder (alumina), which is cooled and stored for further use.

The entire process is based on caustic so any overflow or drain of vessel need to be taken back into the process. So, catching points are located at different locations across the plant. The job of

the catching point is to collect the slurry (grinded bauxite mixed with caustic) by using gravity and pump the slurry back to process. Those pumps are called sump pumps.

The number and rating of pumps varies from plant to plant. The number can surpass 150 and rating starts from 5 HP (Horse Power unit, equal to 746 W) and may go beyond 100 HP as per requirement and process volume. Important to mention they, are installed with a redundant setup. Most of the time those pumps are operated manually and neglected, as it is not considered a mainstream equipment. But its number and cumulative energy consumption cannot be neglected.

During initial stage of installation different solutions like level sensor or float type proximity switches are installed to optimize the running time but over the operating time, they are damaged because of scaling and remain bypassed or out of operation which results in high energy consumption.

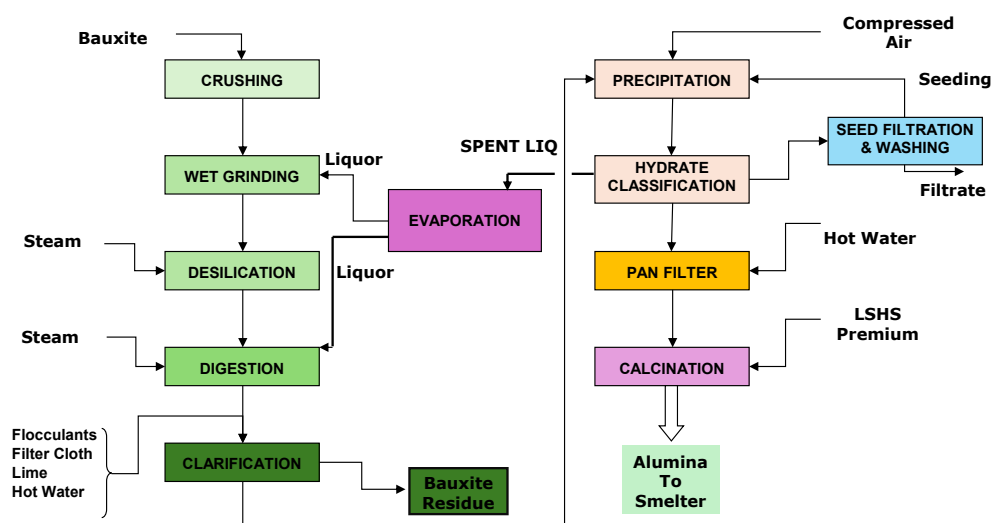


Figure 1. Basic Bayer process flow diagram.

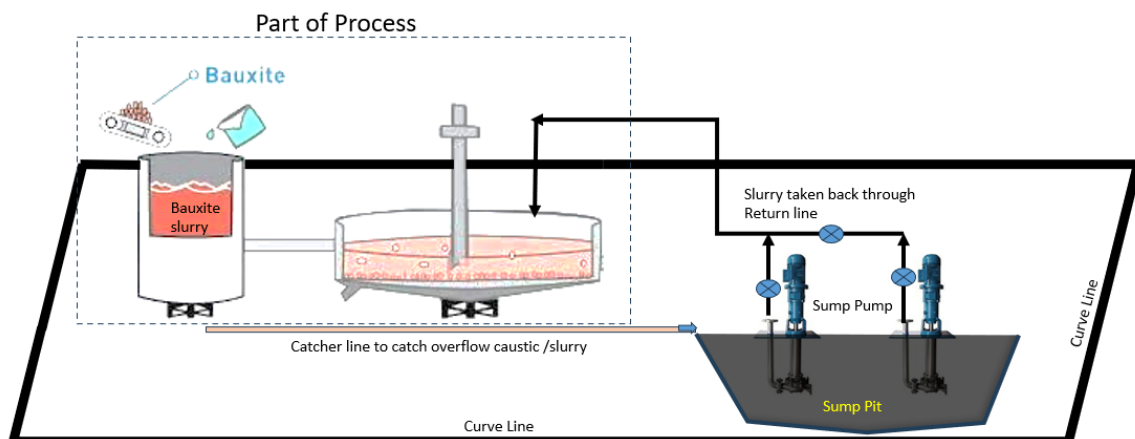


Figure 2. Sump pump installation location.

1.1 Working of Sump Pump

A sump pump is a device used to remove slurry/caustic/rainwater that has accumulated in a sump pit. Sump Pit is a basin dug into the lowest part of the curbed area. Slurry naturally flows into this

pit due to overflow, rain, or drainage from the vessel. When the slurry level in the sump pit reaches a certain height the sump pump is switched On and turned Off when the pit gets emptied.

The motor operated pump's impeller spins, creating a centrifugal force that pushes the slurry up through a pipe and take it back to the process. Regular maintenance is necessary to ensure the sump pump functions properly. This includes checking the pump periodically, cleaning debris from the pit, and testing the pump to ensure it activates correctly.

In alumina refinery sump pumps are installed at different places to collect overflow/washing caustic. The objective is to reduce the wastage of caustic by taking it back to the process. The area operator is the owner of this system, and the installed assets are shared with other shift operators who works at the same location but in different shift.

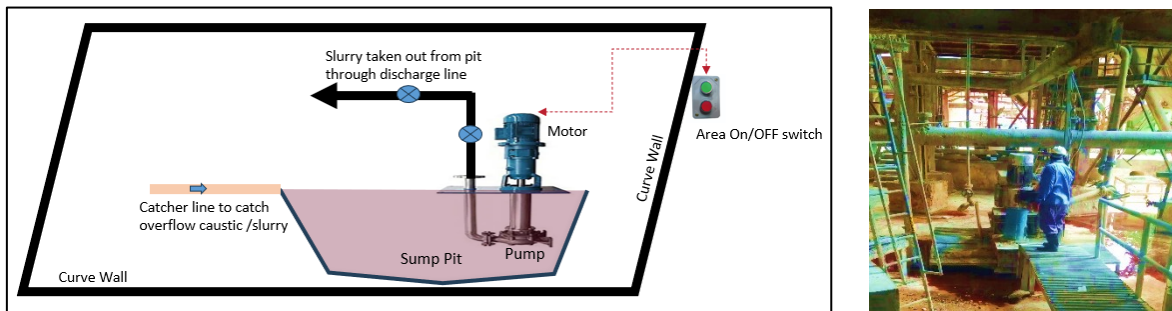


Figure 3. Typical sump pump installation diagram.

1.2 Why It Is Important in Alumina Refinery

The sump pump plays a crucial role in managing water and liquids within various processes and areas in an alumina refinery. Overall, sump pumps are indispensable in alumina refineries for maintaining operational efficiency, ensuring environmental compliance, protecting equipment, and safeguarding the health and safety of workers. Their role extends beyond mere water removal to encompass critical aspects of refinery operations and environmental stewardship.

1.3 Energy Consumption-Pain Area

The specific energy consumption of alumina refineries varies from 11.5 to 13.5 GJ/t which depends upon design and production volume. The electrical energy is approximately 10 % to 12 % of total energy consumption. The high energy consumption can be caused by multiple factors like low efficiency of the process, wrong selection of equipment, idle running equipment, etc. Energy consumption contributes around 30 % to the alumina cost of production in the Indian subcontinent. The distribution of energy as per category is shown in Figure 4.

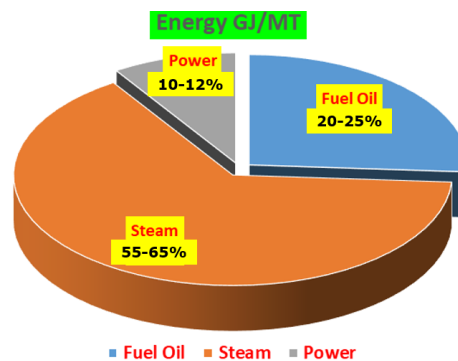


Figure 4. Energy consumption distribution.

The sump pumps contribute significantly to this value because of its number. It has been observed that the running time of sump pumps varies from 1 to 12 hours, on average, depending upon season, its installed location and process condition.

During the trial time of 62 days (in two stages: 15 days + 47 days) it has been observed that a sump pump of 50 HP, operates in average for 7.3 to 7.5 hours in a particular location of refinery, as shown in Table 1.

While analysing the reason for the high running time, it has been observed that the sump pump operates in islanded or in silo mode. It means the pump is operated by the area operator and is not connected to any centralized system. Its operational or process data are not documented in any system. Most of the time, because of human error, the running time increases.

Table 1. Sump pump at normal condition.

	A	B	C = B2 - B1	E = B/A	F	G = F2 - F1	H = G/A
Sl No	Trial	Reading (kWh)	Difference (kWh)	Daily Consumption (kWh/d)	Reading on hour-meter (h)	Difference (h)	Daily running time(h/d)
1	Trial #1	20 696	1 599	106.6	284.28	109.94	7.32
2	(15 days)	22 295			394.22		
1	Trial #2	10 605	5 381	114.49	22.85	211.93	7.5
2	(47 days)	15 986			234.78		
Average kWh consumption				110.55	Average Running time/day		7.41

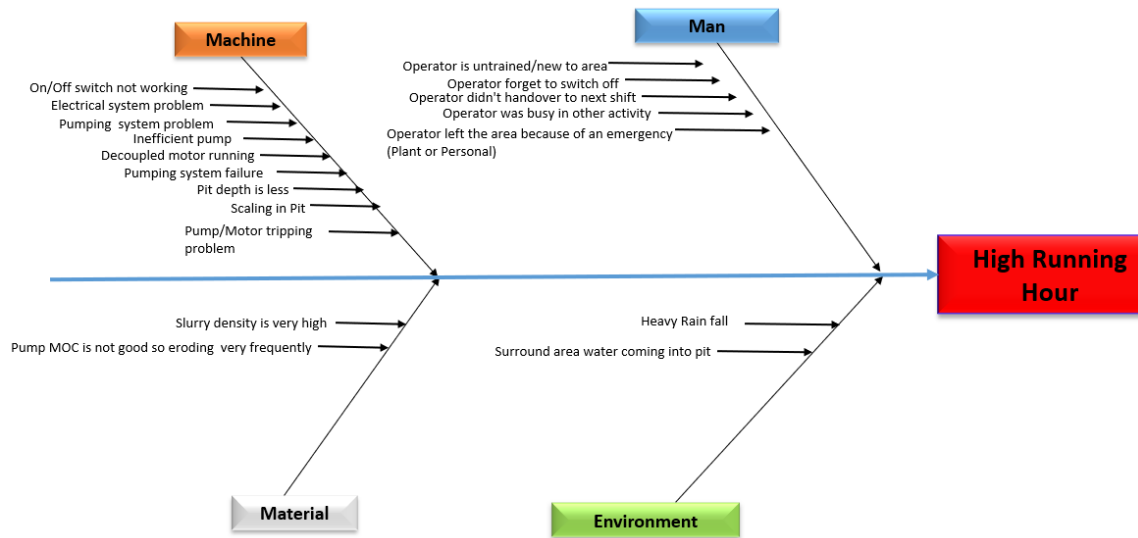


Figure 5. High running time cause & effect diagram.

It is not that basic automation like float & level sensor were not tried before to control the running time but because of the nature of process slurry the float and the level sensor gets covered with slurry scale. Cleaning the scale is also a tedious job and most of the time the sensors get damaged during cleaning.

Safety issues also appears while cleaning and approaching towards inclined pit which is filled with caustic slurry. The interlock of sump pumps with pit temperature was also tried but failed because the temperature setpoint need to be changed continuously because of different temperature of process fluids and weather temperature changing every hour.



Figure 6. Slurry scale in pipe from sump pump.

1.4 Proposed Solution

The sump pump coupled with induction motor and electric motors typically operate most efficiently between 50 % and 100 % of their rated load. The peak efficiency is generally around 75 % of rated load. Efficiency decreases notably when motors operate below 50 % of their rated load. In this range, motors are considered underloaded due to the significant drop in efficiency.

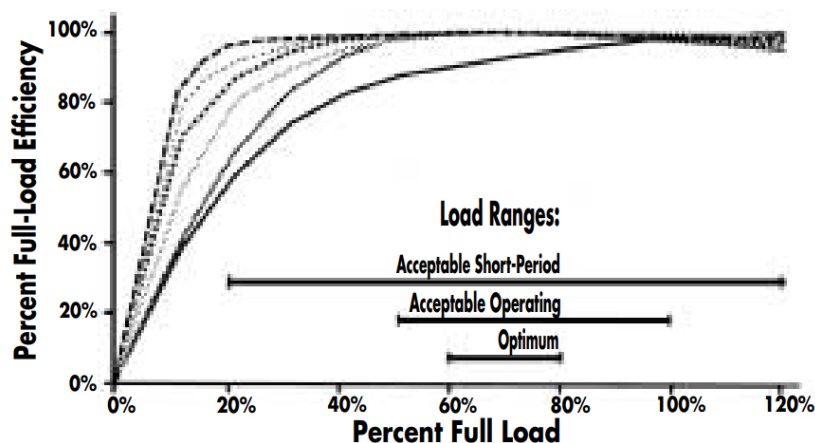


Figure 7. Motor load efficiency.

(Source: Determining electric motor load and efficiency - U.S. Department of Energy)

The electric current consumption of a sump pump varies with changes in speed and torque as shown in Figure 8. Since most sump pumps operate at a fixed speed, fluctuations in load are a dynamic factor. The load on the pump or motor is influenced by the condition of the sump pit – higher when the pit is full and lower when it is not.

Torque and current are closely related; thus, underload current can serve as a parameter to potentially reduce energy consumption by triggering motor shutdown. Monitoring underload current can help detect when the pit is empty, thereby reducing idle running hours, hence energy saving.

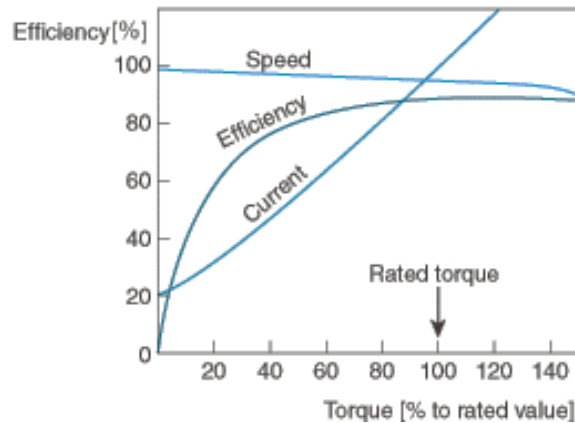


Figure 8. Graph of efficiency, current and speed vs torque for induction motor. (Reference: 2-3-3. Characteristics of Induction Motors | NIDEC CORPORATION)

2. Benefit

An experimental setup with an Energy meter, underload current controller, hour meter connected on the motor control circuit, so it can measure the running time through "Hour Meter", record the energy in "Energy meter" and trip the motor through "Under load Current Controller". To configure the "Underload Current controller" we took the current consumption trend of sump pump especially during the empty condition and configured based on reading. The setup is shown in Figure 10.



Figure 9. Experimental setup with energy meter, hour meter and underload detector.

Table 2. Meter reading after using under load current as monitoring parameter

	A	B	C = B2 - B1	E = B/A	F	G = F2 - F1	H = G/A
Sl No	Trial	Reading (kWh)	Difference (kWh)	Daily Consumption (kWh/d)	Reading on hour-meter (h)	Difference (h)	Daily running time (h/d)
1	Trial #3 (6 days)	19 583	71	11.83	254.78	4.5	0.75
2		19 654			259.28		
1	Trial #4 (8 days)	22 594	409	51.125	287.28	18.95	2.37
2		23 003			306.23		
Average kWh consumption				31.48	Average Running hour/day		1.56

Trial #3 and Trial #4 ran for approximately 14 days and the pump tripped 79 times. While analysing the results it was observed the trips are during lunch, teatime and in shift change over time, when the area surveillance is minimum. The tripping frequency is shown in Figure 10.

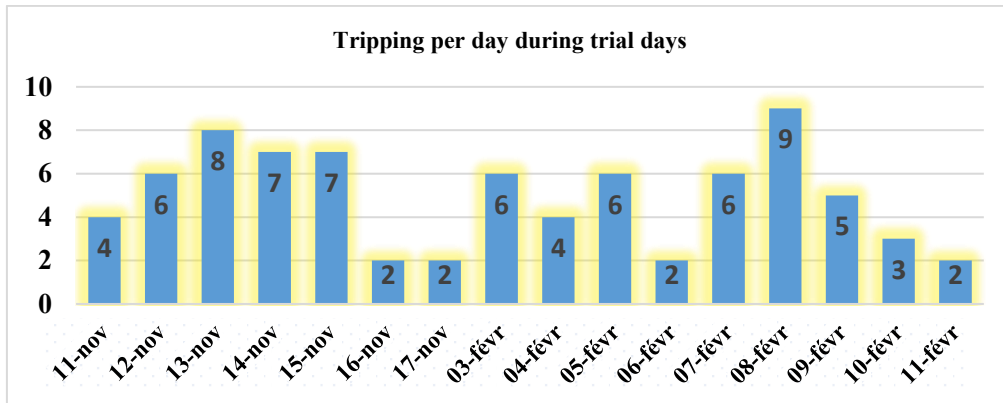


Figure 10. Daily tripping trend of sump pump after imposing underload current as tripping factor

Table 3. Comparison of trials

Condition	Trial	Daily Consumption (kWh/d)	Daily running time (h)
Normal condition	Trial #1 (15 days)	106.6	7.32
	Trial #2 (47 days)	114.49	7.5
With Underload current tripping	Trial #3 (6 days)	11.83	0.75
	Trial #4 (8 days)	51.125	2.37

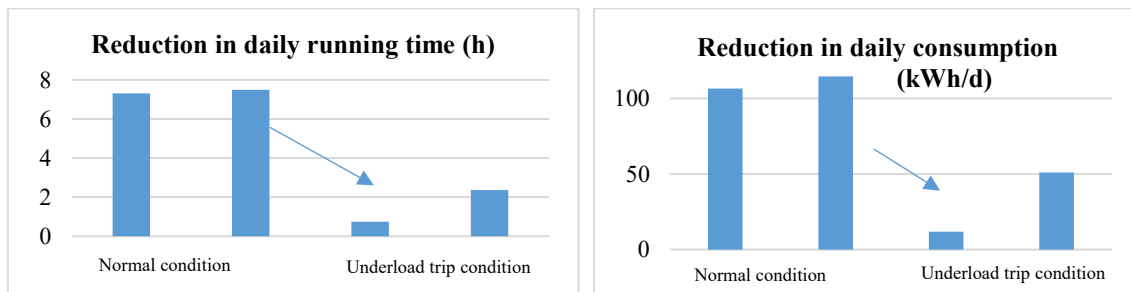


Figure 11. How the underload current setting impacted the daily energy consumption and running time

Based on the observed trend, implementing underload current monitoring as a tripping point can significantly reduce energy consumption. Specifically, this measure has shown potential to decrease average energy usage from 110.55 kWh/day to 31.48 kWh/day. By utilizing underload current as a trigger for motor shutdown, energy efficiency can be greatly improved, reflecting a substantial decrease in power consumption over time.

3. Conclusions

The alumina refinery sector is recognized for its high energy consumption, making it an intensive industry within the aluminum sector. Approximately 1–2 % of global greenhouse gas emissions are attributed to aluminum production, with up to one-third of these emissions stemming from the thermal energy required in its initial processes. It was observed, in industrial conditions, that

underload current can play a crucial role in reducing energy consumption in an alumina refinery. From the experiment it was observed that approximately 79.07 kWh per day can be saved from a single 50 HP sump pump. The saving will become significant with the increase in number of pumps.

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