Power Supply Outages to Cells in Aluminium Smelters

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Abstract

The need for the reliability of power supply to the cells in the aluminium reduction process is well known. However, there was a peak of outages in the period 2008 to 2011 coinciding with the start up of new large smelters and the reliability of supply to Western smelters is still not improving. Readily available data over the last fifteen years is provided. This data is used to develop a high level root cause analysis, which is used to provide suggestions for a way forward.

Keywords: Reliability of power supply to aluminium reduction cells; power interruptions to smelters; root cause analysis.

1. Introduction

Unlike data that is systematically collected on the reliability of power station by the Electrical Research Institute [1], there is little analysis of power outages in aluminium smelters. Nevertheless, the need for reliability is well known, particularly for outages greater than two hours when modern cells start to freeze and restart becomes problematic. Some outages can cost up to hundreds of millions of dollars.

This paper builds on previous papers [2] to [6]. A comprehensive, but not necessarily complete, list of outages has been compiled and analyzed. While not necessarily totally accurate, enough examples are available to give a reasonable picture. Any feedback would be appreciated. All smelters, excluding China, are included in the analysis. China is only excluded as the data is not readily available and can be confusing with many more stops and starts to fit power availability and market conditions.

2. History

A history of fifty outages including a few near misses over the last fifteen years are listed in Table 1, with references listed from [7] to [45]. A history of outages by year is shown in Figure 1, separated into Larger (> 500 000 tpy) and Smaller smelters.

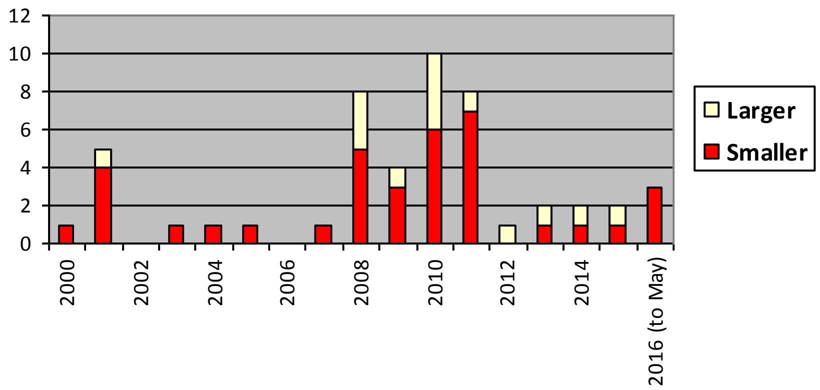

Figure 1. History of power outages by year.

Table 1 – Source of power outage in last 15 years

			A – Initial Location			B – Equipment or system							C – Type or event				D – Equipment Age			Comment
Plant	**Ref**	**Date**	1 Plant or Main Switch Yard	2 On Site Power Station	3 Grid or offsite PS	1 Bus Bar	2 Rect-ifier	3 Trans-former	4 Switch Yard	5 Trans-mission line	Cells	6 Other circuit break protect equip. DNS Tube leaks. Earth faults. Flood	1 Fire/ Elect/ Flash over	2 Mech	3 Light-ning	4 Failed Protection Poor Response Poor Procedures Poor Design Other	1 0-5 y	2 5-25y	3 Old >25 y	0 >5000 000tpy xx two outages x one outage DNS :Did not start
2000																				
Mt Holly	3	10/3	x			x							x					x		Bus bar failure
2001																				
St Jean-M	7	14/2	x								x		x					x		Basement Thermite
Albras	3,8	1/6			x						x					x			x	Power shortage
Hillside	3	14/9			xo							xo				xo			xo	Air compressor dns
Warrick	9,10	5/12		xx								xx				xx			xx	Unreliable equipment
2002																				
2003																				
Alumar	3,11	18/7	x				x						x					x		2 rectifier failures
2004																				
Ormet	12	Nov	x								x			x					x	Labour strike
2005																				
Korba	13	2005		x								x				x	x			PS shut. Inexperience
2006																				
2007																				
2007																				
Alcoa Ten	14	16/4	xo						xo						xo			xo		Lightning,Power line broken
2008																				
Portland	15	18/6			x					x				x				x		Broken 500kV line
Anglesey	3	12/6	x					x					x						x	132 kV transformer
Dubal	3,16	2/11		x								x				x		xo		Thermal overload
NZAS	3	9/11			x			x					x					x		Transformer failure
Korba	17	22/11	x									x	x				x			Overload/Breaker failure
Korba	17	2007	x								x			x			x			Power surge/Metal leak
Korba	17	2007/9		xx+o								xx+o				xx+o	xx+o			Boiler tube failures Some near misses

2009																				
Noranda	18	1/1			x					x				x					x	Ice storm/broken lines
Jal	19	May		x								x		x			x			Boiler tube failures
SaZ	20	17/8			xo							xo		xo				xo		Water Turbine intake vibration
Sohar	21	2009		x								x				x	x			Control circuit/near misses
2010																				
Jal	22	23/4		xo								xo		xo			xo			Inexperience ops
Laterriere	3, 23	7/7	x					x					x					x		Transformer failure
Hindalco Hirakud	24	Jul			x							x			x			x		Heavy rain, lightning
Qatalum	25	9/8			xo				xo							xo	xo			Power out, Earth fault, trips
Century Grund	3,26	1/9	x						x							x		x		Nationwide power out 36KvBreaker fail, dns
Isal Strausvik	26	1/9			x					x				x				x		Nationwide power out
Dubal	27	22/11		x								x				x		xo		Grid down, concurrent maint
Alba	28	21/11		xo							xo			xo				xo		Emergency repair. Pots dns
Fjardaal	3	18/12	x					x					x					x		Transformer explosion
Kubal	29	23/12	x					x								x		x		35Kv transformer cable
2011																				
St Jean	30	Jan			x					x		x	x					x		Booster group dns
Dunkerq	31	May, Aug	xx					xx					xx						x x	Two transformer incidents
Portland	32	27/8	x					x								x			x	22kV trans
Aluar	33	Nov	xo						xo							xo		xo		Flooding elect cabinets
Lynemth	34	16/11	x									x	x						x	Circuit breaker failure
Shawwing	34	end		x					x							x			x	
2012																				
Century Grund	35	11/1			x				x				x					x		Offsite substation
Qatalum	36	17/3		xo								xo	xo				xo			Fire.Sea water

																				cooling. Near miss
2013																				
Press M, Mukah	37	27/6			x							x	x				x			Frequency drop
Ma'aden	38	15/10	xo						xo							xo	xo			Unstable cells/transition joints
2014																				
EGA	39				x							x`				x	xo			Inexperience. Line 2, after 7 month Lost turbine
Noranda	40		x								x					x			x	Pot failures
2015																				
Ma'aden	41	30/4	xo						xo				xo				xo			Short ground cable
Press M, Bintulu	42		x								x		x				x			Basement Thermite fire
2016																				
Noranda	43	9/1	x						x							x			x	Supply circuit failure
Aardal	44	1/2			x						x					x			x	Power outage
Indal	45	10/2			x						x					x			x	Power shortage
outages smelters> 0.5mtpy,			3	7	4	0	0	0	4	0	1	9	2	4	0	9	6	5	1	
Outages Smaller smelters			19	6	11	1	1	8	5	4	8	10	15	5	2	13	9	14	15	
Total Smelters			22	13	15	1	1	8	9	4	9	19	17	9	2	22	15	19	16	

On inspection it is apparent that there was a significant increase in the period 2008 to 2011. This coincided with the startup of a significant number of new, Larger smelters in the Middle East and India, with most suffering. Currently these 17 Larger smelters represent 48 % of production, but only 15 % by number.

Since that time outages have increased from the lower base power to 2008.

A high level summary of the frequency of outages is shown in Table 2.

Table 2. Recorded outages in all plants (except Chinese) over the last 15 years.

	No of Smelters	No of Outages	Av Period (years)
Large or soon to be large smelters	17	14	8
Small smelters	96	36	15
Total	113	50	

It is likely that there have been additional outages in the smaller plants that have not been widely reported. Nevertheless, analysis of the data in Table 2 suggests that at a minimum:

Frequency of faults for Larger smelters	1 / 10 years per plant
Frequency of faults for Smaller smelters	1 / 40 years per plant
Frequency of faults for all smelters	1 / 34 years per plant

3. Root Cause Analysis

There is not enough data in the public domain to carry out a detailed Root Cause analysis (RCA) such as outlined in [46] and Figure 2. Nevertheless, it would be useful for individual outages to be investigated in detail by smelter operators.

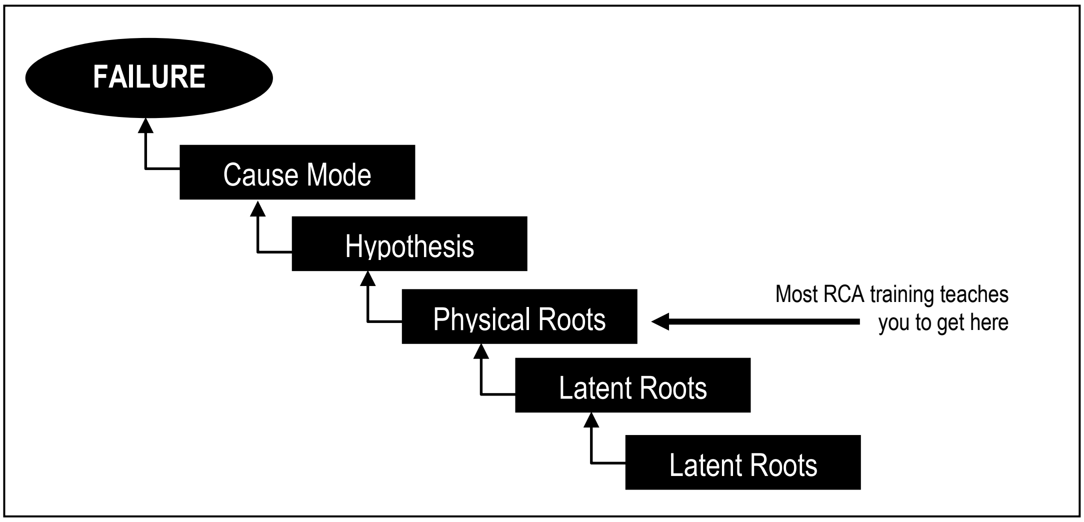

Figure 2. Root Cause Analysis – Life Cycle Engineering.

However, using the data available in Table 1, a basic high level RCA can be obtained by grouping failures and near misses into location in the supply chain of the plant, on site power station(s), or in the grid/of site power stations; source of equipment or systems failure, e.g., bus bar, rectifier etc; and type of failure or event, e.g., fire, electrical flash-over, etc.

Further breakdowns are also useful in the age of the system and size of smelter.

The variants in technology have not been assessed as all aluminum smelters use the same basic Hall-Heroult technology and internationally procured equipment.

Analysis of the fault data is shown, by number of outages in relation to the age of the equipment, in Figure 3.

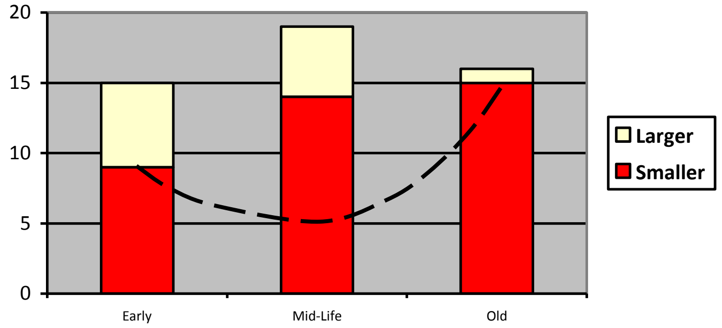

Figure 3. Number of outages in smelters (and equipment) of different ages.

Outages over time are greatest in the mid-life of the smelter. This is in sharp contrast to a classical failure history of individual components with a typical failure history that is lowest in Mid-Life.

Also, high outage rates for new large smelters is apparent.

A classical failure history is superimposed for individual components, and large smelters reported separately.

This analysis indicates that a number of failures are grouped in the early life of the smelter as would generally be expected, as a result of inexperience and preliminary failures, but most unexpectedly occur in the mid-life of the smelter. This is due partly to the grouping of a large number of components, with different equipment lives, but also reflects the many system failures.

These differences indicate that many of the outages are due to a systems breakdown, rather than an equipment breakdown, and points to the need for more effort to a maintenance reliability approach [9] and systems engineering, management approach organization and audit [52].

In Figure 4a, the number of the outage is shown plotted against the location of the main blocks of the plant and in figure 4b, against the nature of the effective company control.

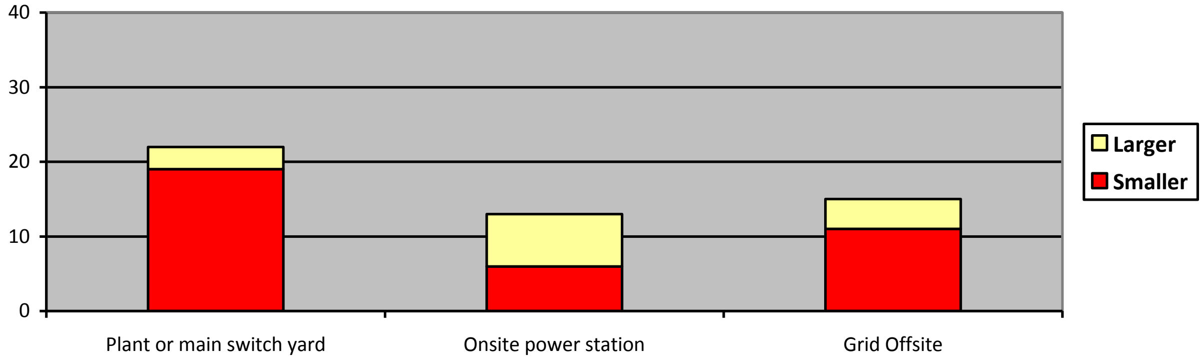

Figure 4a. Location of outages in main blocks of the plant.

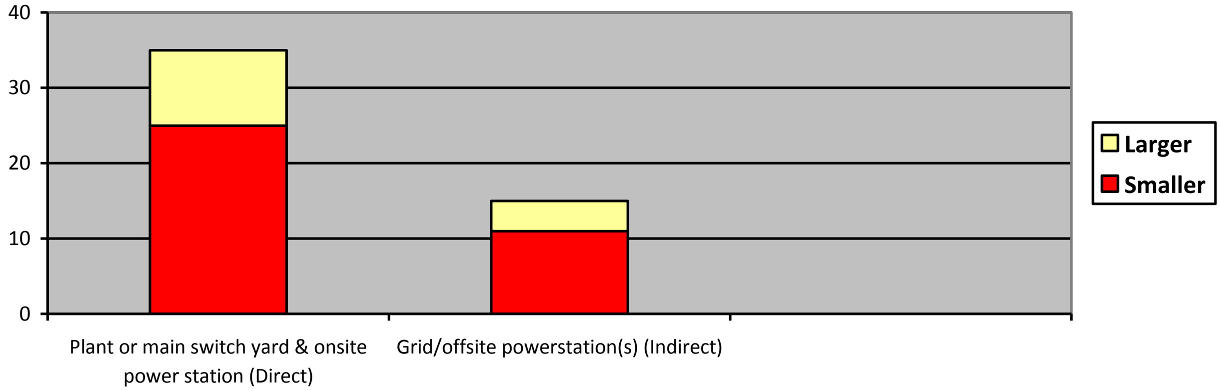

Figure 4b. Effective company control.

On inspection, it is apparent that the plant or main switch yard has the most impact. Collectively the processes within which the operating company has effective control are larger than the grid/offsite.

Nevertheless, both need effective (but different) management so as to achieve control.

There have been a large number of major grid failures globally, [54] and with increased financial pressures in the future in a wide range of countries these are likely to continue. Operating in this environment will require additional efforts so as to be able to maintain indirect control over the reliability of these systems.

In Figure 5, outages are grouped into type of equipment.

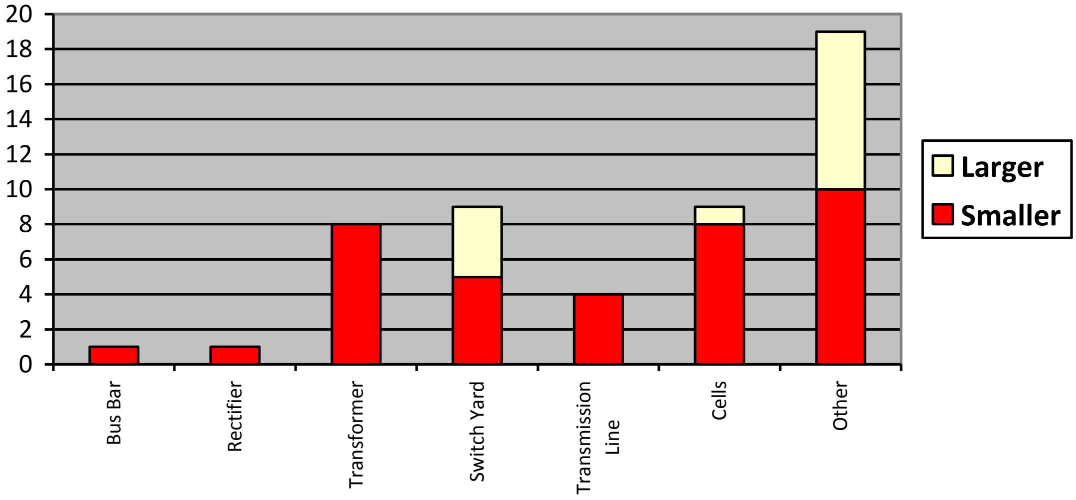

Figure 5. Outages grouped into type of equipment.

By far the largest group is of "other", including protection equipment, circuit breakers, unreliable equipment, boiler tube leaks, earth faults, flooding, equipment did not start, etc. Again, this points to systems failures.

Of the large items of equipment, the main equipment involved in outages were transformers, switchyard as cells, including leakage resulting in bus bar failures or thermite fires [53].

In Figure 6, outages are grouped into event/result of the failure.

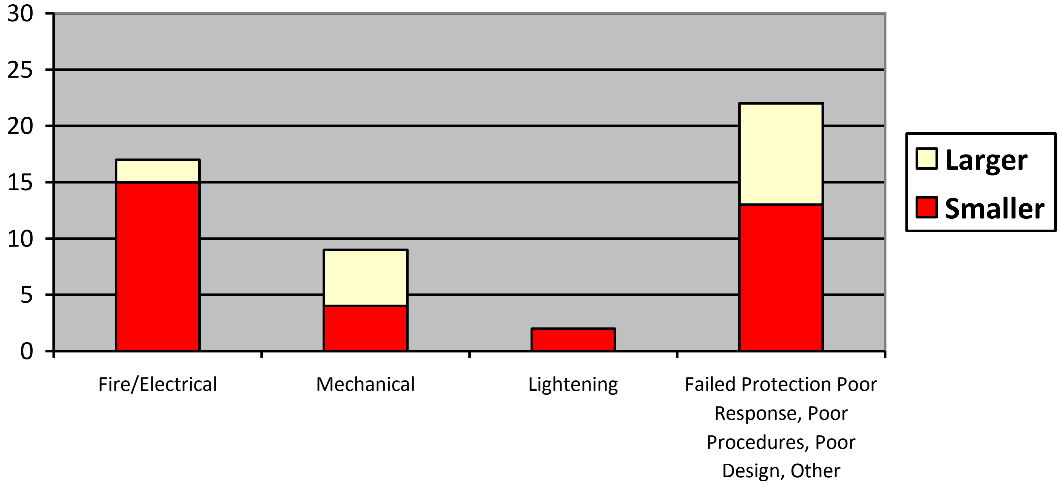

Figure 6. Outages grouped into event /result of failure.

Again, the largest group involves systems engineering and operational management training.

Following the large number of protection type failures in new large smelters, improvements have been made as outlined in [47] to [51]. However, more needs to be done so as to maintain and operate these complex systems.

In addition, particular vigilance is required to develop, record, organize appropriate management structures, train and then audit the startup, shutdown and restart major electrical and equipment circuits.

Further check lists are outlined in [6].

4. Conclusions

Power outages (and also major safety accidents) should be reducing in the future, and each company maintaining meaningful databases of typical root causes is difficult due to a limited sample size. The various aluminum associations have stopped out of this field.

It would be useful for all producers if each company published its own high level root causes in their press releases and or annual reports. This would allow easier analysis and encourage improvement so as to be more competitive than other metals.

This paper outlines the importance of a focus on system design, maintenance, organization and smelter management and audit both for processes under direct as well as indirect control.

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