Reprint from International Aluminium Journal, January/February 2013

Power upgrade of Isal potlines
Most challenging and advanced power upgrade ever realized

In 2012 Rio Tinto Alcan Iceland (Isal) accepted the delivery of four new rectiformers from ABB to feed all three potlines from a new 220 kV AIS step down substation. This is truly the most challenging and advanced power upgrade ever realized in an aluminium smelter.

Power upgrade of Isal Potlines 1-3

B. Jonsson, RTA; M. Wiestner, ABB

The most challenging and advanced power upgrade ever has been realised in an aluminium smelter. In 2012 Rio Tinto Alcan Iceland (Isal) accepted delivery from ABB Switzerland of four new rectiformers which now feed from a new 220 kV AIS step down substation all three potlines at Isal. The project history and technical challenges will be described.

RTA Isal at Straumsvik, Iceland

In the period 1959 to 1971 the Government of Iceland was keen to develop power intensive industry to utilise the hydro power resources of Iceland, of which at least 30 TWh/a are considered economically harnessable and not of major conservation value.

In the early 1960s contacts between Alusuisse and the Ministry of Industry soon became formal negotiations, which in 1966 concluded with a master agreement on the engineering and construction of the facilities in Straumsvik for the production of aluminium. A power contract was also concluded between the National Power Co., Landsvirkjun, and the Icelandic Aluminium Co. Ltd (Isal), a sole subsidiary of Alusuisse.

The Isal Smelter was constructed in several steps, from part of Potline 1 inaugurated in mid-1969 to Potline 3 entering into operation by mid-1997.

In the middle of the 1980s the electrolysis pots of both elder potrooms were replaced by a then recently developed new type, so called cradle pots, which had more thermal expansion capability than their predecessors. The purpose of this development by Alusuisse was to raise the current intensity of the potlines from then 104 kA to some 120 kA, which is the rated current for each of the rectifier stations A and B for the Potlines 1 and 2, to which totally eight rectifier units are assigned. Rectifier unit B4 was modified to serve as a booster rectifier for test purposes and connected to 20 pots in Potline 2 for current tests up to 20 kA around 1990. By the middle of the 1990s, the rated current, 120 kA, was already achieved for 320 pots in Potlines 1 and 2.

Back then, Alusuisse looked for further investments and pursued the option of a new potline with identical pots but with bigger and magnetically optimised DC-busbars. The rated current intensity of Potline 3 is 135 kA with four rectifier units. In 2000 the filter system for rectifier C was extended to enable current intensity above 140 kA and in 2004 the fifth rectifier was added to maintain (n-1) operability of the rectifiers.

By 2004, the current intensity in Potlines 1 and 2 had reached 125 kA. Then the filter system for rectifier B, whose reactive power demand is higher than that of A, was extended and the current intensity raised gradually to its present value of 133 kA.

The present value of the current intensity in Potline 3 is 168 kA, and since November 2011 there is a 20 kA, 100 V DC, booster rectifier operated to achieve 181 kA on ten test pots in Potline 3.

The substation and rectifier equipment serving Potline 1 is from the Swiss company Oerlikon, and that for Potline 2 is from the Swiss company BBC. Both companies are predecessors to ABB, a consortium composed of the Swedish Asea and the Swiss BBC. ABB was in 1995 the successful bidder for the power system in the substation extension and new Rectifier Station C for Potline 3 in Straumsvik.

There are three different current control systems for the potlines of Isal. Rectifier A comprises diodes, rectifier transformers and regulating transformers with On-Load Tap Changers (OLTCs) from Maschinenfabrik Reinhausen (MR) in Regensburg, Bavaria, extremely reliable equipment. The Potline 1 current fluctuates, but is kept constant with an accuracy of ±0,1 kA within a 24 hours interval.

Rectifier B comprises diodes, rectifier transformers with saturable reactors of voltage range ±30 V DC, and regulating transformers with OLTCs from MR. This equipment provides for constant current control for Potline 2. Rectifier C comprises thyristors and rectifier transformers with constant current control and fast load-shedding capability, and with a very big range of load gradients for Potline 3.

Each rectifier station has its own current control system with their pros and cons. In Potline 1 the current is fluctuating. The control algorithm optimises the number of steps so as to simultaneously minimise both the number of diverter switch operations and the long-term current deviation from the setpoint.

Rectifier stations B and C provide for constant current with regulating transformers. These are rectifier transformers with saturable reactors and diode rectifiers in B, respectively rectifier transformers and thyristor rectifiers in C. Each system has its advantages and disadvantages, but the superior controllability of a thyristor rectifier is unquestionable. This is advantageous to achieve quick and modulated load shedding. On the other hand, this feature is not useful for multiphase voltage dips deeper than 50%, because we then need to release the thyristors from the grid to avoid wrong triggering damage to the thyristors. In an island grid like the Icelandic one, such dips tend to occur about once a year.

The introduction of programmable logic controllers at Isal in 1990 gave rise to optimised potline current control and to enhanced open circuit protection. This has supported the search for higher current and energy effi-

Largest transformer in Iceland

220 kV AIS (Air Insulated Substation)

ciency, as well as for fewer anode effects, thus reducing the release of greenhouse gases. The merit of Isal in this context is high on a world wide scale.

The modern control technique has also served to enhance safety in the potrooms. Huge power will be concentrated in a pot in which the potline circuit is broken at high current. Such an event is catastrophic to personnel in the vicinity, to the superstructure of the pot and to equipment in the vicinity. In 1991, Isal, supported by an entrepreneurial mechanical engineer and software expert from Berkeley University, Hafliði Loftsson, started data collection to develop a protective algorithm in an empirical manner. This software development proved itself soon successful in Potroom 1, in which arc prediction and protection has avoided any arc flash across pots since its introduction.

This scheme was then adapted to the different dynamic of Potroom 2, and soon after start-up of Potroom 3, it was adapted to the much more dynamic control characteristic of Potroom 3. This protection scheme has to be adopted by the parallel operating old and new rectifiers.

132 kV GIS (Gas Insulated Switchgear) operated at 60 kV

Scope background

On 19 June 2006 ferroresonance struck the voltage measurement transformers on the secondary busbar of the stepdown transformers for Rectifier Station C, feeding Potline 3. Subharmonic oscillations occurred between the inductances of these VTs and the capacitances of the 33 kV cables feeding the five rectifier transformers. This caused excessive voltage across the VTs and huge overloading. Floating power systems are prone to this phenomenon under raised voltage conditions, as was the case here at midnight during midsummer. What triggered the ferroresonance was a change in the active and reactive load, when Potline 3 was being taken to zero current due to a certain pot-tending need.

Voltage measurement on the delta busbar of the fixed ratio 220/33 kV, 51 MVA, Single Phase Stepdown transformers serves mainly to provide a reference signal to the gate control of the thyristors. When this input measurement disappeared, the rectifiers became inoperable, which resulted in freezing of the pots.

In spite of successful cold restarting of the 160 frozen pots in the period 16 July through 31 August 2006, this event cost at least USD30 million. Therefore Isal undertook a number of minor improvements from June 2006 to January 2007 to avoid a reoccurrence of this rare phenomenon. However the major risk mitigation still remained to be realised.

In December 2006 the then owner of Isal, Alcan, carried out a due diligence analysis on site Straumsvik with experts of Isal to evaluate the power supply availability to the three potlines. This Hazop Risk Analysis revealed severe weaknesses in the design of the main power supply, when confronted by a number of common mode failure scenarios. It was obvious that these weaknessess could only be corrected by major strengthening of the power system.

The concept chosen in a specification made by Isal and Alesa, an engineering company of Alcan and now of Rio Tinto Alcan (RTA), was to design a new 220 kV bay feeding 2 x 75 kA, 900 V DC, swing rectifier units of thyristors, thus virtually bypassing the existing power supply system. The swing rectifiers can be operated in parallel with each of the rectifier stations A, B and C, serving all three potlines. The rated power capability of this enhanced reliability system is 200 MVA on the 220 kV side and 150 kA, 900 V on the DC side. The normal operating voltage of the potlines is only 720 V DC, while the high voltage capability allows for restarting a potline on the verge of freezing, e.g. after a grid failure, as there is then no reserve power supply for the Isal smelter.

In March 2007 a referendum was held in the nearby municipality of Hafnarfjördur, a few kilometres from the existing smelter in which the public rejected a new smelter for Isal. Then Isal proposed a plan B of enlarged production capability of the existing smelter from 190 to 230 kt/a with a potential for further creep. This was approved by the new owner, RTA.

The concept is to add a stepdown transformer, 200 MVA, and two thyristor rectifiers, 75 kA, 900 V DC, dedicated to Potlines 1 and 2 for the creep concept. The idea is to continue operation of the four old rectifier units for each of the Potlines 1 and 2 as the most valuable part of this equipment has a remaining lifetime of some 30 years. Then normal operation will constitute four old units at some 112 kA and a new unit at some 74 kA (in total 186 kA) in Potlines 1 and 2. This can also be accomplished in (n-1) operation.

Two out of three plant power transformers were upgraded from 15 to 30 MVA. One of them was needed to cope with higher load of the gas treatment centres for the pot fumes, and the upgrade to cope with an electric furnace in the casthouse to homogenise extrusion billets. Billets are a new product type of Isal, replacing the hot rolling slabs.

The feeder of the plant power transformer supplying auxiliaries of Potline 3 was relocated from 33 kV busbars to the new 60 kV GIS-busbars. The latter are equipped with sectionalisers enabling load transfer between stepdowns on each 220 kV line without affecting the potline operation, which is a step forward for Isal. The reason for preferring GIS to AIS was lack of land at the seaside of the substation.

The benefit of the feeder relocation is not only for higher reliability of the power supply. It also means that the 15 MW power formerly allocated for plant power can now be transferred to the rectifier station, thus yielding 180-185 kA permissible current intensity from rectifier station C, instead of 168 kA previously.

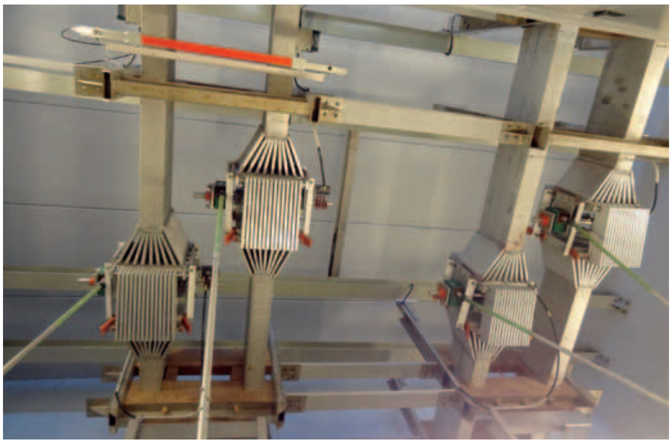
The new power contract with the National Power Co. and the transmission agreement with the TSO, Landsnet, is for delivery of 425 MW at power factor over at least 0,98 for a calendar month. In addition to this high reactive power compensation, the TSO also requested thorough filtering of harmonics, keeping each voltage harmonic under 1,0% and the total voltage distortion factor below 1,5% at the Isal 220 kV intake.

This demanded a sophisticated engineering of 2x85 MVA filters connected to the 60 kV busbars.

Immediately useful

Overhaul of transformers and rectifiers was postponed under the IPU Construction Period to avoid a crowded construction area and to reduce production loss and disturbances to the electrolysis. This would have inflicted considerable losses to Isal, as it was not possible to weld busbars on full potline current intensity. This is the main explanation for the higher than expected fault rate of equipment under the commissioning period. One regulating transformer failed in each of the rectifier stations A and B, and then, at short notice, the new rectifier sections A5 and B5 had to be temporarily put into operation in order to keep full potline current, 133 kA. The transformers tap changers were repaired on site.

While leakage in a rectifier transformer in station B was being repaired, the damping units for one of the rectifiers B took fire. Then only two old units were available for Potline 2. This would not have been a sustainable situation for this potline, i.e. its current intensity would have been 80 kA only out of 133 kAm or 60%. The electrolyte temperature would have approached its freezing point while repair of the damping unit took place. It is likely that some pots would have been lost, and the operational stability and efficiency of others would have been adversely affected. The electrolysis costs and lost revenue due to such a serious situation can be estimated to USD1,5 million. As new units were made available to the Isal operation by ABB, full current intensity could be kept in the potline during this critical situation.


Busbar system with FOCS (Fibre Optic Current Sensor)

All this delayed the hot commissioning and disturbed the schedule of ABB; however, ABB, its subcontractors and Isal gained valuable experience.

Spooky damage to control equipment like coils and control valves was observed during this period. We identified the origin by analysing the voltage quality on the 60 kV busbar feeding the new plant power transformer, which supplies the auxiliary voltage to the new system, S, and the existing system C. With new rectifier units in operation without any filter ON, the voltage contains a lot of harmonics with Total Voltage Distortion Factor, TVDF=10. It was therefore decided to modify the control concept of the filters. Instead of being switched on when the reactive power demand is about 30 MVAr, the first part of the filter is switched on after switching on the first rectifier transformer, but before it is loaded. With the filter of the third harmonic on, the voltage is a true sinus curve, and the voltage quality is even higher when switching on the filter for the fifth and eleventh harmonic as the first part.

Conclusion

The fruitful cooperation between ABB Switzerland and Isal has now lasted for about 45 years from the engineering of the power and control system for Potline 1 in Straumsvik until the commissioning of the 4x75 kA rectifier units and their power supplies in autumn 2012. This cooperation has been beneficial to both parties.

Icelandic companies have never played so big a role in realisation of an ABB project in Straumsvik as in the IPU Project. Orkuvirki has erected all the equipment and has engineered and assembled a number of switchgear and controlgear units. Staki has developed the software of the master controller of each potline as well as the software of the supermaster and of the SCADA. All this has been accomplished in good relationship with the owner of the systems, Isal, which has been closely consulted at each stage and made contributions to the technical developments as well.

The technical infrastructure delivered to Isal is in accordance with the technical specification made jointly by Alesa, an engineering company of RTA in Zürich, Switzerland, and Isal, prior to the bidding process of the IPU project.

The power and control system of the substation of Isal is a state-of-the-art solution for the complicated task of extending a power distribution system of an over 40 years old aluminium smelter in full production. This was accomplished without any injury and without any major damage to the smelter's equipment.

Isal looks ahead to a prosperous future of an ever increasing production capacity, higher productivity and improved reliability of power supply to the electrolysis pot lines and to the plant as a whole.

Authors

Bjarni Jonsson is leader of Electrical Services of Rio Tinto Alcan, based at Icelandic Aluminium Ltd, Straumsvik, Iceland.
Max Wiestner is manager of the business group Primary Aluminium which is part of the ABB Global Product Group, based in Dättwil, Switzerland.

Contact us

Global Product Group Aluminium

ABB Switzerland Ltd.
Segelhofstrasse 9P
CH-5405 Baden 5 Dättwil
Switzerland
Phone: +41 58 586 84 44
E-mail: max.wiestner@ch.abb.com

For contact details, please visit our website:

www.abb.com/aluminium