Upgrade and Innovation of a Multivariate Process Parameters Intelligent Control (MPPIC) Technology for Aluminum Reduction Cells

Yi Xiaobing[1] and Tian Qinghong[2]
1. Vice Chief Engineer
2. Department manager
CHALIECO GAMI, Guiyang, China
Yi Xiaobing: yxbgami@163.com

Abstract

An advanced Multivariate Process Parameters Intelligent Control (MPPIC) technology was developed by CHALIECO GAMI several years ago and has been used in many large domestic and foreign Greenfield or modernized brownfield smelters. In this paper, the new up-grading and innovation research resulting from MPPIC technology developed by CHALIECO GAMI in recent years will be described and the successful application of this latest technology, especially with the "Remote Data-Diagnosis Technology Service" (RDTS), will be introduced, too. The new upgraded MPPIC results in significantly higher current efficiency and reduced energy consumption for some smelters and is superior to the original MPPIC technology which it can replace.

Keywords: Multivariate Process Parameters Intelligence Control (MPPIC), cell control model, cell computer network control platform, Remote Data-Diagnosis Technology Service (RDTS).

1. Introduction

Over the past decade, the original MPPIC technology and device [1] with independent intellectual property rights developed by CHALIECO GAMI has reached the international level and achieved great reputation in China and abroad with excellent product quality and technical service. However, with the rapid development of world primary aluminum industry, especially the Chinese primary aluminum industry during this decade, it also faces more and more intensive competition. Therefore, how to further reduce the production cost becomes one of the key tasks for each aluminum smelter. According to the report [2], the average power cost of Chinese primary aluminum industry amounts to more than 44 % of total production cost and is about 16 % higher than the average in the rest of the world. So, how to reduce the specific energy consumption per kg of aluminium is by all means the priority for the aluminum smelters in China.

Based on several cell control technologies research and application achievements in recent years, especially on original MPPIC technology developed by CHALIECO GAMI, this latest technology is more efficient, energy-saving and emission-reducing control technology system for aluminum reduction cells. It takes advantage of theoretical research and successful practical implementation of the cell intelligent control systems in China and abroad and uses the in-depth research of cell control technology software and hardware at its core. To further achieve the obvious economic and social benefits based on the existing conditions for Chinese primary aluminum industry, the MPPIC technology has been first implemented on the large pilot Centre Worked Prebake (CWPB) anode cells and are now used in several large CWPB cell lines.

The latest generation of MPPIC technology is developed from the original generation. It could enable each large Point Fed Prebake (PFPB) reduction cell to achieve the best technical and economic key performance indicators with high current efficiency and low energy consumption under stable production conditions of minimum operator interference. This is not only the

development direction of intelligent pot control systems for primary aluminum industry, but also the new innovative development model for continuous increase of the performance of the aluminum reduction cells.

2. The Concept of the Latest MPPIC Technology

Everybody knows that the aluminum reduction process has strong interaction multivariate characteristics with limited observable process and responses which are non-linear and vary over a wide range of time scales. Figure 1 shows a diagram of main interactions between mass and energy balance.

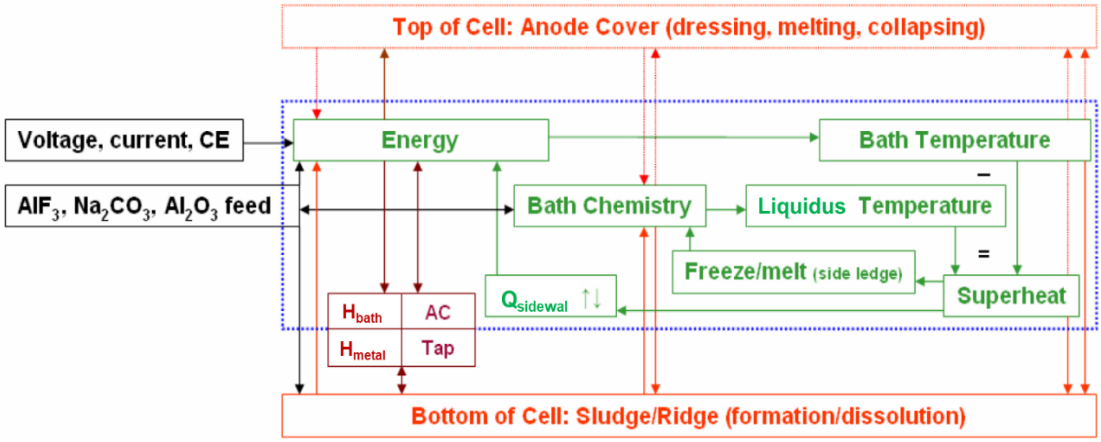

Figure 1. Overall interactions between mass and energy balance [3]. H_{bath}, H_{metal} are bath and metal height, $Q_{sidwall}$ is sidewall heat loss.

The first main successful step of the original MPPIC technology was that both mass balance and energy balance control of single reduction cell were included, which means that AlF_3 could be automatically fed and excess AlF_3 in the cells could be controlled more accurately [1].

Generally speaking, pilot cells should be built and tested before they would be put into construction and production for each kind of new larger PFPB cell lines. But in fact this cannot be done for most kinds of new cells, especially in China.

Nevertheless, the final performance of the cells depends on every step of its Engineering, Procurement, Construction, and Management (EPCM) procedure. The latest MPPIC technology just takes better account of the above EPCM interaction factors, which is suitable for all kinds of the PFPB cells; it can give the cell not only more accurate control, but also find some problems especially for energy balance and solve these problems better quickly.

The cell operation and performance depends on several parameters such as design current, anode current density, working voltage derived from voltage balance, etc., referred to as the "static balance" parameters of cells. The cell is impacted also by other factors like the materials selection and installation during the construction period, preheat and process control in early operation. This is particularly true for various complicated bath compositions of cells in Chinese aluminum smelters, where the best "static balance" of cells can only be realized by good control of the "dynamic balance" parameters, which includes the mass and energy balance parameters in the original MPPIC technology, such as alumina concentration, excess AlF_3 and voltage balance; in particular, high current efficiency requires an ideal cell-cavity shape, which is very important for ideal cell heat balance. Good "static balance" is the basis of ideal cavity shape and the condition

for good cell integral performance. Superheat is the bridge between the “static balance” and the “dynamic balance”, and the most important parameter for regulating these two balances.

Considering that the cell cavity shape is very important, the latest MPPIC technology presents a new concept, the "cell status analysis system”, which includes hardware and software innovations in this advanced technology.

Figure 2 shows the relationship between “static balance” and “dynamic balance”, as well as the interaction with related key operating parameters for aluminum reduction process. How to treat such mutual relationship is the key to reach excellence in high current efficiency, energy saving and emissions reduction. As shown in Figure 2, “superheat” as the bridge is the key in the whole cycle.

The bath has a liquidus temperature (or melting-point temperature) which is the function of its composition and depends strongly on the concentrations of excess AlF_3 and alumina [3]. Bath temperature is the sum of liquidus temperature and superheat. The bath superheat depends greatly on both, cell “mass balance” and “energy balance”. The “energy balance” changes the superheat by forming and melting the side ledge profile which changes the amount of molten cryolite in the bath and changes the concentration of excess AlF_3 and alumina.

The superheat is mainly the result of cell energy balance, but it is affected mutually by the impact of “mass balance” on “energy balance”. It shall be indicated especially here that the cell “energy balance” depends on current efficiency, bath height, metal level and liquidus temperature.

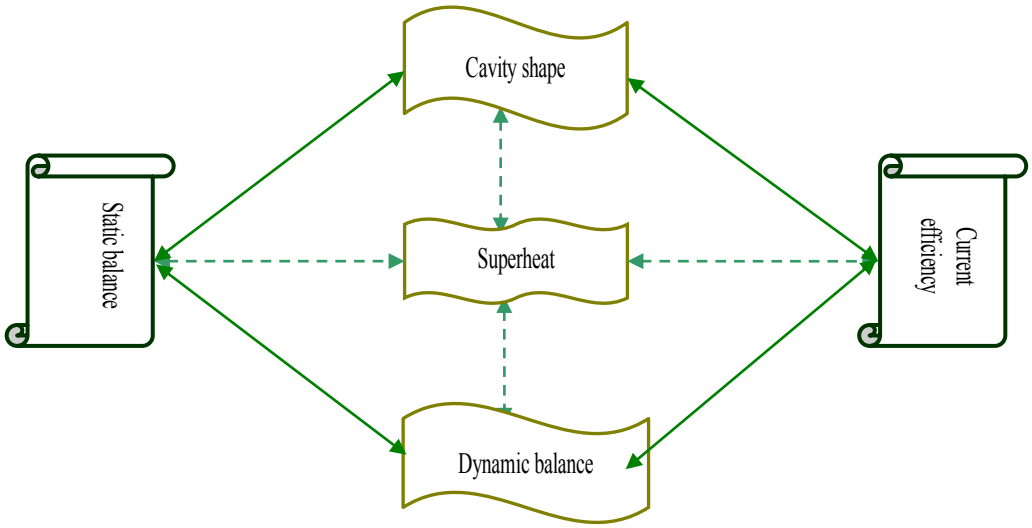

Figure 2. Relationship between “static balance” and “dynamic balance”.

3. Upgrade Innovation of Control Model and Control System

The main characteristic of the original MPPIC technology was to make analysis and deductions on the measured data of the cell and the data generated during cell control, carrying out the identification of “superheat” and online control of excess AlF_3 in “dynamic balance”. This was a first in Chinese cell control technology, with its original control model as shown in Figure 3.

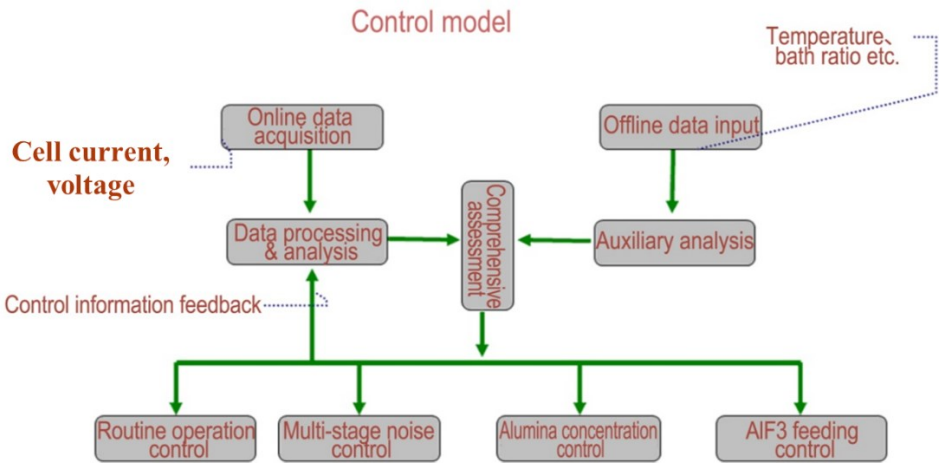

Figure 3. Control model of the original MPPIC technology.

Such control model can be applied in the basic computer network control platform as the shown in Figure 4.

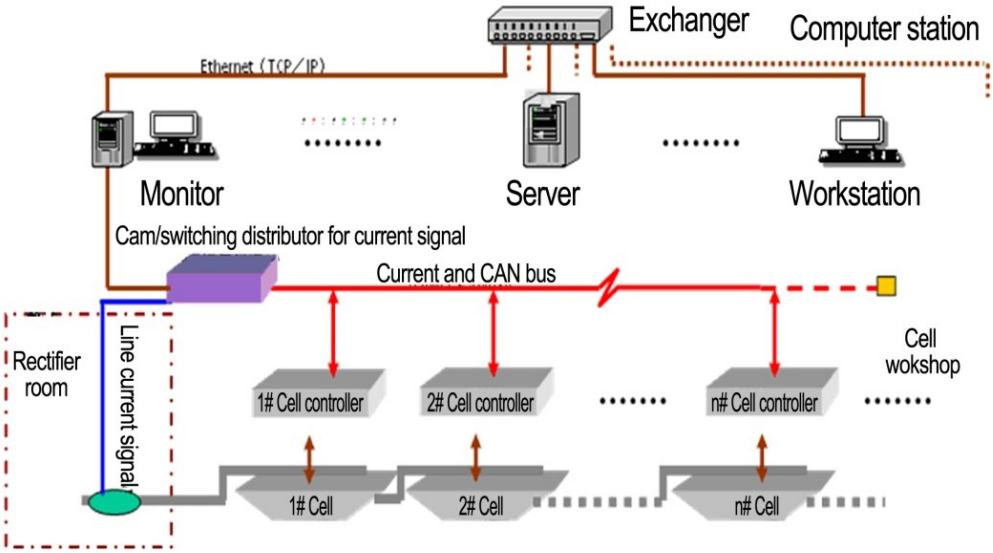

Figure 4. Basic cell computer network control platform.

However, the most important feature of the latest MPPIC technology is to build up one completely new "cell condition analysis system" shown in Figure 5, after adding some hardware measurement devices such as "accurate tapping device", "high-precision anode stroke measurement device" and "intermittent automatic cell temperature measurement device", and improve the "comprehensive assessment" function in the control model of the original MPPIC technology. Each newly-added computer feedback, thus contributes to more accurate "alumina concentration control" and "AlF_3 feeding control". Moreover, the latest control model also covers the whole set of process controls on "fume treatment plant (FTP)" and "alumina circulating conveyance system" affecting directly the "energy balance" and "mass balance" during reduction process flow, which not only reduces greatly the specific DC energy consumption but also the overall AC energy consumption per kg of aluminum and the total fluoride emissions in the system. This results in sustainable high current efficiency, energy saving and emissions reduction.

The control model of the latest MPPIC technology is shown in Figure 5.

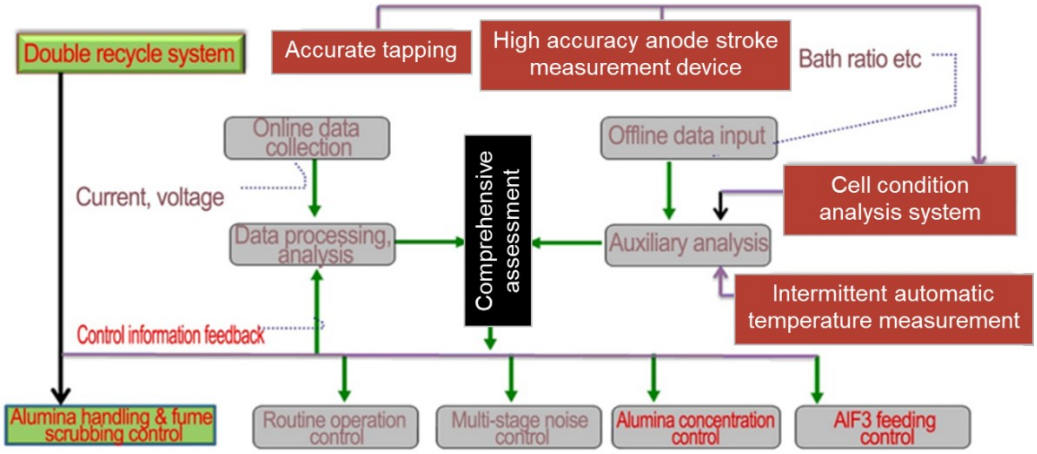

Figure 5. Control model of the latest MPPIC technology [4].

The control model of the latest MPPIC technology can be applied in the Computer Network Control Platform designed for plant as shown in Figure 6.

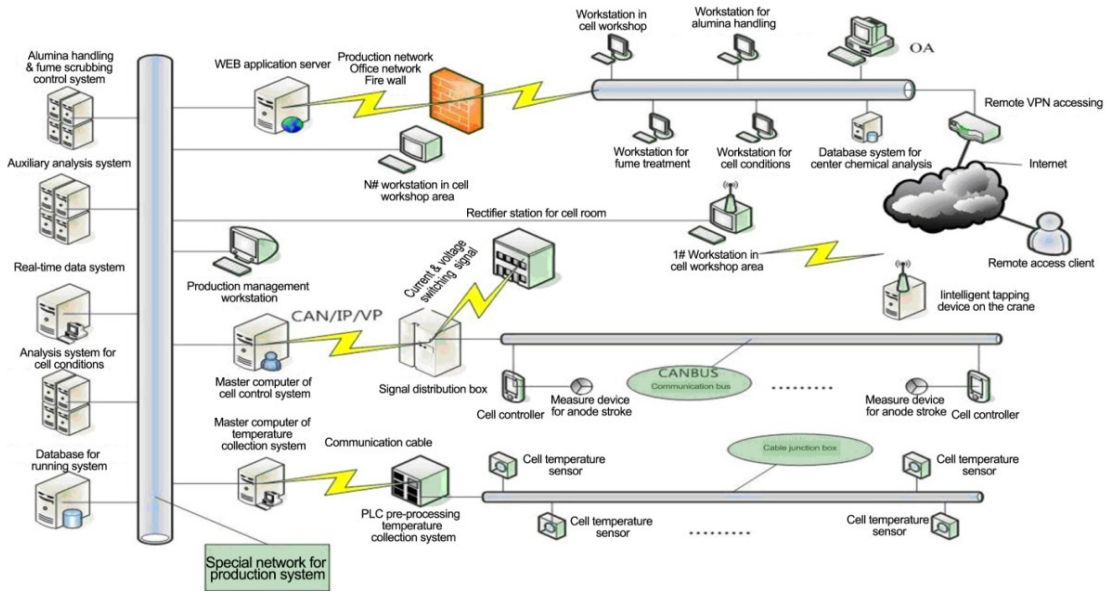

Figure 6. Cell computer network control platform for the latest MPPIC system.

The upgrade and innovation of the original MPPIC technology not only improves the original MPPIC software for single cell but also brings the monitoring and control for mass and energy flows in primary aluminum production process. Also the hardware of corresponding control systems is upgraded.

4. The Upgrade and Innovation main contents of the MPPIC Control Technology

With the high speed development of specialized hardware of the GAMI in recent years, such as the cell controller technology, the upgrade and innovation of the MPPIC control technology also made a great progress for the specialized software at the same time:

4.1. Main Specialized Hardware Upgraded and Innovated

- The Cell Controller upgraded:

Based on the many measuring devices developed in GAMI, such as high-accuracy double-pulse generator for measuring the position of the anode in the cell, the cell controller is upgrading and innovating from GAMI-VI type to GAMI-VIII type during these years.

- The Intelligent Crust Breaking Device innovation:
  In order to know well the alumina feeding status automatically, the intelligent crust breaking device is innovated and is controlled by the cell controller through the variation of the compressed air pressure with the crust breaker cylinder.

4.2 The Upgrade and Innovation of the Specialized Software

- The Upgrade of the Original Specialized Software:
  Based on the accuracy increase of all kinds of the special instruments and the upgrade of the original specialized software, such as "the double-tracking alumina feeding control", "the multi-mode AlF_3 feeding control and the fuzzy superheat identification" as well as "the fuzzy tapping amount deduction", etc. There is a great improvement for the parameter identification and control accuracy.
- The Innovation of the New Specialized Software
  With the innovation of the intelligent crust breaking device, "the cell conditions analysis system" software is upgraded a lot. The cell operating trends could be getting more and more sequential with this software.

The normal sequential variation trends controlled between the main operating parameters in the cell are shown in Table 1.

Table 1. The normal sequential variation trends in the cell.

Bath Temperature	Noise	Voltage	AL_2O_3 Feeding	ALF_3 Feeding	Metal Level	Bath Level
Up	Down	Down	Down	Up	Down	Up
Down	Up	Up	Up	Down	Up	Down

5. Development of the Latest MPPIC Technology with RDTS

With the development of internet and big data technology in the aluminum industry, GAMI has also developed the Remote Data-Diagnosis Technology Service" (RDTS) with the partners and smelters. It is based on the MPPIC technology of GAMI and internet connectivity as shown in Figure 7.

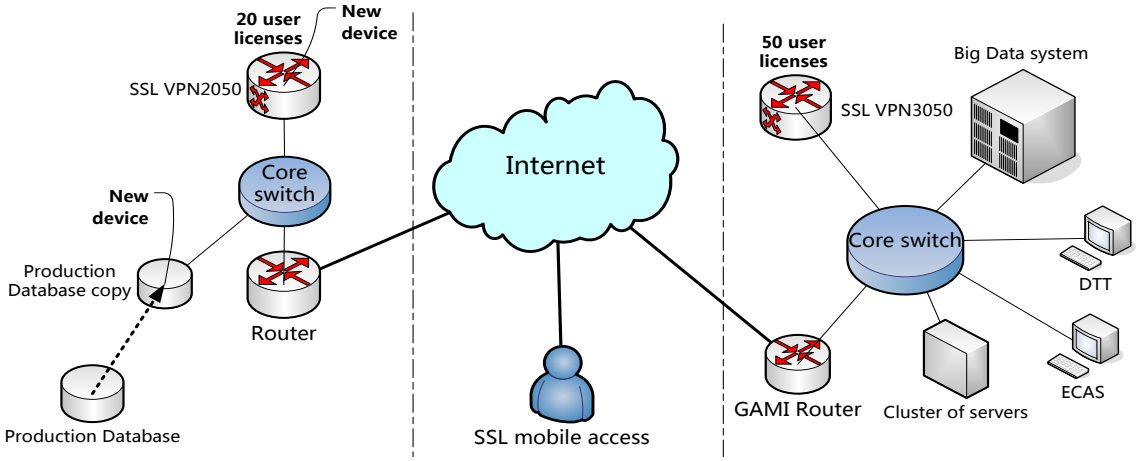

Figure 7. The Remote Data-Diagnosis Technology Service" (RDTS).

The RDTS work center is located in GAMI as shown in Figure 8.

Figure 8. The Remote Data-Diagnosis Technology Service" (RDTS) work center.

Now GAMI gives RDTS support to smelters with internet connection. Weekly and monthly meetings are held between the licensed smelter technical people and GAMI's experts working in the following fields:

- Presentation of the dynamic key performance parameters and their evolution,
- Presentation of automatic analysis and diagnosis results,
- Special concerns and difficulties of the reduction cells that need to be solved in discussion with the experts,
- Some project and plan evaluation as well as communication of technical information,
- Etc.

This work is completed on the basis of MPPIC and RDTS, which had been developed in the smelter and GAMI with internet platform and software tools. It will be also possible to share the real-time information. By using mobile phone, the manager will be able to know the condition of any individual pot anywhere and anytime in the near future.

6. The Application Example and the Result of the Latest MPPIC Technology with RDTS

During recent three years, almost 5 Mt capacity of the greenfield and brownfield smelters cell lines have applied the latest MPPIC technology of the GAMI in the world. And the agreements have been reached on RDTS between GAMI and four smelters up to now. Figure 9 shows the analysis and diagnosis results in one smelter of G300 (320 kA) reduction cell line.

Generally after almost half to one year application, based on the MPPIC and RDTS, the process parameters adjustment of the whole reduction cell line have been improved a lot and the economic benefit also has been improved remarkably as follows:

- Improvement of standard operating practices,
- Improvement of safety in cell operation and reduction of accident risk on the cells,
- Improvement of the potline average current efficiency by 0.5 % to 3 %,

- Decrease of the potline average energy consumption by 0.15 to 0.50 kWh/kg Al,
- Increase of cell life and decrease of cell relining cost.

	A	B	C	R	S	T	U
1				Val Section 1st DIAGNOSE Date:2017-4-14			
2				Category	Phenomenon	Reason	Solution
3	No.	PotST	Age				
4	1101		C796	A			increase set Voltage 20mv
5	1102	Stop					
6	1103		D1175	B	High B/T	Low M/L	retain metal -500kg
7	1104		B1570	A			
8	1105		D1017	C	noisy,Low M/L	bad cavity	set ALF3 @ half =20kg
9	1106		C161	A			
10	1107		D1475	B	High B/T	Low M/L	retain metal -500kg
11	1108		B488	B	High B/T	Low M/L	retain metal -500kg
12	1109		D208	C	Low M/L,Low B/T	bad cavity	set ALF3 @ 0
13	1110		D1793	D			
14	1111		C605	A	Low B/T,noisy	High M/L	tap more metal +100kg
15	1112		B2125	B	High B/T	Low M/L	retain metal -500kg
16	1113		B1689	B	High B/T	Low M/L	retain meta -500kg
17	1114		B1734	C	Low B/T,High Ex.ALF3	Low M/L	set ALF3 @ half =20kg
18	1115		B1849	D	High B/T,Low Ex.ALF3	Low M/L	retain metal -800kg
19	1116		C1074	A	noisy	Low Voltage	increase set Voltage 20mv
20	1117		C762	A	High B/T	High Voltage	Voltage decreased,weigh ALF3 fedder
21	1118		B249	A			
22	1119		C960	A	High B/T,Low Ex.ALF3	Low ALF3 Feeding	increase set ALF3 =35kg
23	1120		B582	B	High B/T,Low Ex.ALF3	Low ALF3 Feeding	ALF3 feeding already increased
24	1121		C430	A	High B/T,Low Ex.ALF3	Low Voltage	increase set Voltage 20mv
25	1122		C1071	C	noisy	bad cavity	reduce set ALF3 =20kg
26	1123		C617	C	Low M/L,Low B/T		set ALF3 @ half =20kg
27	1124		C925	C	Low M/L,Low B/T		set ALF3 @ half =20kg
28	1125		D748	A	High B/T,Low Ex.ALF3	Low ALF3 Feeding	weigh ALF3 feeder
29	1126		C1775	D	noisy	Low M/L	increase set Voltage 20mv
30	1127		C147	A	Low B/T		set ALF3 @ 0
31	1128		D1082	B	High B/T	Low M/L	retain metal -500kg
32	1129		B172	A	noisy	High M/L	tap more metal +200kg
33	1130		C803	A	High ALF3 Feeding	High M/L	tap more metal +100kg
34	1131		B377	B	High B/T	Low M/L	retain metal -500kg
35	1132		C461	A	Low B/T,noisy	High M/L	tap more metal +100kg

Figure 9. Example presentation of analysis and diagnosis results in RDTS.

7. Conclusion

GAMI belongs to CHALIECO and CHINALCO, which have good record and reputation in the field of pot control technology not only in China but also in many other countries. An innovative model of the pot and its control technology has been developed by GAMI design and research team. This confirms that more and more intelligent technology will be applied in the cell operation resulting in higher current efficiency and lower energy consumption as well as less pollution in the aluminum electrolysis industry.

8. References

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