The Computer Integrated Process System of Aluminum Plant

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Abstract—The computer integrated process system for aluminum production uses computer integrated technique, decision support system, real time expert system, fuzzy control technique, etc. This system consists of 4 levels: upper levels (i.e., business management and production coordination) and lower levels (i.e., supervisory control and direct process control), the former is belonged to management information system, and the later is belonged to process control system. Because of taking a lot of measures, this computer integrated process system has been successfully implemented in an aluminum plant and has made a remarkable effect of saving electricity and increasing aluminum production.

I. INTRODUCTION

Computer Integrated Manufacturing System (CIMS) is a new technology occurred in 1970's. Its implementation in continuous process industry is called as Computer Integrated Process System (CIPS).

Fig. 1 shows hierarchical structure of CIPS [1] for an industry plant. The real tasks of upper levels (level 4 and level 3) are production scheduling and management information, and those of lower levels (level 2 and level 1) are control computation and control enforcement.

In an aluminum plant, there are two major production processes, i.e., aluminum electrolysis and coke calcination.

To implement CIPS in a whole aluminum plant is both a very difficult work and a risk thing. Even so, an attempt for CIPS of an aluminum plant was made. Although aluminum production process has its special characteristics, the integrated technique and the integrated software platform presented in this paper may be a reference for other continuous processes.

II. THE PROCESS CONTROL SYSTEM

A. The control level

1. Duties of the control level

- Maintain direct control of the plant units under its cognizance.
- Detect and respond to any emergency condition which may exist in those plant units.
- Collect information on unit production, raw material and energy use and transmit to higher levels.
- Service the operators' man/machine interface.
- Perform diagnostics on itself.
- Update any stand-by systems.

Fig. 2 shows a block diagram of a generalized primary level control system.

2. Aluminum electrolysis process control

1) Process model

Current density and interpolar distance are major parameters which effect the electrolysis cell heat. When the electrolysis cell structure and dimension of the anode are determined, the heat loss depends on the voltage at cell terminals or the interpolar distance. If the interpolar distance

Fig. 1. Hierarchical computer control structure for an industrial plant

Fig. 2. A block diagram of a generalized primary level control system
is too short, it will cause apparent loss of current efficiency. Therefore, optimum modification of the interpolar distance must both obtain better current efficiency and sustain the electrolysis cell's heat equilibrium. Because measurable mode of the interpolar distance is the cell resistance, modification of the interpolar distance may be implemented by adjusting the cell resistance. A reference resistance model is:

\[ R = (U - E)/I \]

where \( R \) is a reference resistance, \( U \) is the voltage at cell terminals, \( E \) is the counter-electromotive force, and \( I \) is the current that passes through the cell.

2). Control enforcement

Every electrolysis cell is controlled by a controller box. Every controller box is distributed in shops. Its block diagram is shown in Fig. 3. There are three shops (264 electrolysis cells) in this control system.

3). Coke calcination process control

1). Fuzzy control model of the coke calcining kiln

The process of calcining petroleum coke in a rotary kiln is a very complicated exothermic reaction. Mathematically modeling the rotary kiln is very difficult, due to the many interacting physical phenomena governing the behaviors of the solid bed and the freeboard gas. Therefore, based on the method of reasoning and composition[2], a fuzzy control model of the coke calcining kiln is designed, shown as Table 1. In Table 1, CT (calcining zone temperature) and BT (back end temperature) are input variables; CF (coke feedrate), SA (secondary air) and TA (thirdly air) are control variables. \( X_i \) and \( Y_j \) (i = 1~2, j = 1~7, k = 1~3) are elements of the fuzzy sets. For example, when CT is \( X_i^4 \) (OK) and BT is \( X_j^3 \) (slightly low), then CF, SA and TA are \( Y_i^4 \) (OK), \( Y_2^4 \) (OK), and \( Y_j^4 \) (small positive) respectively.

2). Control enforcement

The whole coke calcining process is controlled by a set of distributed control system (DCS). However, the fuzzy control algorithm is installed in an industrial personal computer (PC). Its schematic diagram is shown in Fig. 4.

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**B. The supervisory control level (level 2)**

1. Duties of the supervisory level

- Respond to any emergency conditions which may exist in its region of plant cognizance.
- Optimize the operation of units under its control within limits of established production schedule. Carry out all established process operational schemes or operating practices in connection with these processes.
- Collect and maintain files of production, inventory and raw material, spare parts and energy usage for the units under its control.
- Maintain communications with higher and lower levels.
- Service the man/machine interfaces for the units involved.
- Perform diagnostics on itself and lower level machines.
- Update all stand-by systems.

Fig. 5 shows a block diagram of the supervisory control level.
2. Design of the integrated software system for the supervisory control level

1) Integrated software platform [3]
Integrated software platform is the software development layer based on operation system which opens for application. Its architecture shows in Fig. 6. In the supervisory level, integrated software system consists of two parts: one is the integrated software platform real time database, I/O system, man/machine system and "integrator"; another is development interface provided by the software platform and application software.

2) Application software
Anodic effect is the phenomena that the voltage at cell terminals increases drastically when the aluminum oxide content diminishes from initial value of about 8% to 1 or 2%. Because the aluminum oxide content can not be real time measured on line, how to prevent the anodic effect is a very difficult thing. However, the cell resistance is related to the aluminum oxide content. According to this characteristic and past experience, the related knowledge database is established. An expert system for anodic effect anticipation is attempted. First, obtain the process parameters and loop status from the real time database and establish the variables' past history database; second, perform analysis and judgment with the knowledge database; finally, transmit the result to the real time database and to the lower level simultaneously.

Another challenge task is optimum of aluminum compound. For example, the higher levels get information that certain brand aluminum has a good price in the market. Therefore, the supervisory level gives an optimum result to the control level in order to produce this brand aluminum as more as possible. This task is implemented by a decision support system (DSS).

C. Communication system of the process control system

The communication system of electrolysis cell control selects bus configuration, shown as Fig. 7.

The communication system is based on MINI-MAP (Manufacturing Automation Protocol), which consists of physical layer, data link layer and application layer. Physical protocol is EIA-RS 485 and data link protocol is HDLC.

III. MANAGEMENT INFORMATION SYSTEM

A. The area level (level 3)

This level handles detailed production scheduling and coordination for one of the major plant subdivision. A block diagram of the intermediate production scheduling level is
Duties of the area level:

- Establish the intermediate production schedule for its own area including maintenance, transportation and other production related needs.
- Locally optimize the costs for its individual production area while carrying out the production schedule established by the production control computer system (level 1) (i.e., minimize energy usage or maximize production for example).
- Along with level 4 modify production schedules to compensate for plant production interruptions which may occur in its area of responsibility.
- Make area production reports, including variable manufacturing costs.
- Use and maintain area practice files.
- Collect and maintain area data queues for production, inventory, work force, raw materials, spare parts and energy usage.
- Maintain communications with higher and lower levels of the hierarchy.
- Operations data collection and off line analysis as required by engineering functions. Including statistical quality analysis and control functions.
- Service the man/machine interface for the area.
In the aluminum plant, there are 8 major subdivisions. In this level, there are 32 workstations for carrying out the above duties.

B. The production scheduling and management information level (level 4)

Fig. 9 shows a block diagram of this level.
Duties of this level:
- Establish basic production schedule.
- Modify the production schedule for all units per orders stream received, energy constraints, power demand levels, and maintenance requirements.
- In coordination with required production schedule develop optimum preventive maintenance and production unit renovation schedule.
- Determine the optimum inventory level of raw materials, energy sources, spare parts, and goods in process at each storage point.
- Modify production schedule as necessary whenever major production interruptions occur in downstream units, where such interruptions will affect prior or succeeding units.
- Collect and maintain raw material and spare parts use and availability inventory and provide data for purchasing for raw material and spare parts order entry and for transfer to accounting.
- Collect and maintain overall energy use and availability inventory, and provide data for purchasing for energy source order entry and transfer to accounting.
- Collect and maintain overall goods in process and production inventory files.
- Collect and maintain the quality control file.
- Collect and maintain machinery and equipment use and life history files necessary for preventive and predictive maintenance planning.
- Collect and maintain work force use data for transfer to personnel and accounting departments.
- Maintain interfaces with area level systems.
- Supply production and status information as needed to plant management, sales and shipping personnel, accounting and purchasing departments.
- Supply orders status information as needed to sales personnel.

C. Network system of the management information system

The management information system is based on Novell netware 4.0 Ethernet. The special server AST/586 is the heart of the network system. The development software platform is Foxpro 2.5 for windows. In the network system, there are 40 workstations.

IV. CONCLUSIONS

The computer integrated process system has been used in an aluminum plant for more one year. The aluminum plant
obtains remarkable economic efficiency from follows:
- Saving electricity 750 KWH per ton aluminum;
- Increasing current efficiency 3.1%;
- Increasing aluminum production 2000 ton per year.
- Increasing coke calcination ratio 8.2%;
- Increasing calcined coke 4000 ton per year.
- Improving the product quality.

All these data shows the fact that the computer integrated process system is a practical control method for a continuous process plant.

V. REFERENCES

