ENERGY MANAGEMENT AND CONTROL TECHNOLOGY IN THE NONFERROUS METALS INDUSTRY①

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ABSTRACT

An energy management and control model for nonferrous metals industry was proposed. Based on the model, on-line management and real-time control for the energy process can be completed using computers and distributed structure. As an example of using the energy management and control technology, a distributed computer energy management and control system is given.

Key words: energy management and control real-time computer networks

1 INTRODUCTION

For large scale industrial process, it is important to develop a way of managing and controlling energy. Increased benefits from the judicious use of energy and feedstocks along with the evolution of lower cost and more powerful computers and distributed microcomputer systems have emphasized the role and necessity of effective energy management and control in industry today. In the nonferrous metals industry, it is possible to implement on-line management and real-time control for energy by using computers and distributed structure. This paper proposes an energy management and control model to expound the energy management and control technology in the nonferrous metals industry. Industrial energy management and control technology by improved instrumentation, control and process management is the subject of this paper. As an important example of applying the techno-logy, a distributed computer energy management and control system is presented in this paper.

2 TECHNOLOGY DESCRIPTION

Energy consumed in the nonferrous metals industry includes electricity, coal, coke, oil, water, gas, steam, and compressed air. To achieve scientific management and effective control for the energy process, it is necessary to analyse its property and select an energy management and control model.

2.1 *Energy Process Partition*

The energy process in nonferrous metals factory is similar to that of other industrial plants[1]. It can be divided into the following three parts:

(1) Energy generation, which includes gas generators, boilers and compressors to produce gas, steam and compressed air etc..

(2) Energy transmission, which contains power supply systems, pumps, fans, conveyors, heaters and other auxiliaries etc..

(3) Energy consumption, which is process area primarily for prodution such as the electrolysis process of the nonferrous metals, the drying process of the substances and other equipments driven by steam or electricity.

Some connected components exsit between the above three parts. This explains the necessity of an overall management and coordination strategy for

① Supported by the China National Nonferrous Metals Industry Corporation and the Zhuzhou Smeltery. Manuscript received Sept. 23, 1992; revised Dec. 27, 1993.

the energy process.

2. 2 *Main Tasks*

The scientific management and effective control for the energy process mean that an energy management and control system established in the nonferrous metals factory is generally composed of instrumentation, control and process management subsystems and must preform the following main tasks:

(1) On-line measuring of different kinds of energy parameters.

(2) Automatic control of important equipments and energy subprocess.

(3) Automatic warning of energy process faults.

(4) Real-time centralized supervisory of the energy process.

(5) On-line energy information management and optimization computation.

(6) Real-time energy dispatching decision and overall coordination.

(7) Planning of energy and production.

The above tasks can be allotted to the three subsystems in advance.

2. 3 *Hierarchical Model*

Design of the energy management and control systems in the nonferrous metals industry can use the hierarchical model shown in Fig. 1. The functional decomposition employed is described at the following three levels[1]:

(1) On-line measurement and control, which is a basis level. This level contains the instrumentation and control subsystems. The continuous state information on energy conversion, storage and flow can be measured by the instrumentation in the level. The controls in the level are direct digital controls and are completed by real-time dedicated control systems. They perform specific functions and are designed to be responsive to process transients or disturbances. Simply, by using the dedicated control, the designated variables can be controlled optimally at the desired set point.

(2) Real-time supervisory and management, which is a lower level part of the process management subsystem. This level is generally installed in the local control room. It performs real-time centralized monitoring of energy process, optimizations to coordinate the set points of lower level control systems and management of energy data so that the most efficient overall operation can as a whole be provided. It is expected that a dedicated control system can provide more efficient performance. The basic idea here is to determine the set of set points so that the best performance of the aggregate operation is achieved.

(3) Coordination and planning, which is a higher level part of the process management subsystem. Higher level functions such as real-time energy dispatching decision, overall coordination between optimizing functions, feature planning of energy use and production, and cost scenarios are performed at this level. The output of this level usually provides dispatching commands, plans and constraints. The dispatching commands and plans must be executed at lower level and the constraints satisfied by lower level optimizing functions in order to achieve the overall optimization management and control for energy process.

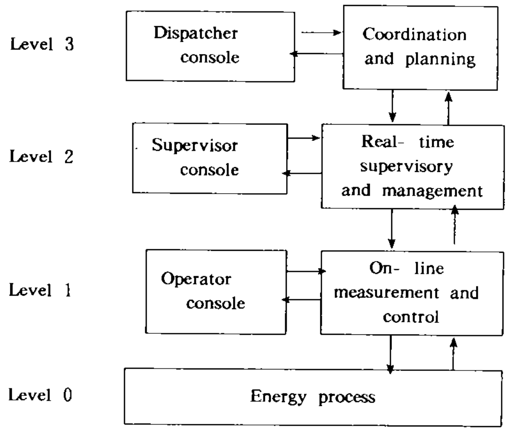

Fig. 1 The block diagram of the hierarchical model

2. 4 *Model Implementation*

Combination of control technology, computer application technology, and management science even makes the design of the energy management and control systems with the hierarchical model possible. Especially for the nonferrous metals factories with decentralized fields, the designed energy management and control systems have distributed structure. Using computers and distributed structure, the hierarchical model can be implemented in the nonferrous metals factories. The implementation must start with low level measurement and control and logically build up to a higher level, leading eventually toward overall energy management and control.

3 THE PRACTICAL EXAMPLE

Using the design and implementation technology based on the hierarchical model, a distributed computer energy management and control system has been estabilished in a nonferrous metals smeltery. It can complete on-line management for all energy and real-time control for a power supply system, four rotary dryers and six gas generators.

3.1 *The System Architecture*

The system uses a distributed architecture, which accords with the hierarchical model and consists of the following four parts:

(1) The central computer system, which contains three IBM PC/XT personal computers used as real-time monitoring computer (RTMC), data management computer (DMC) and energy dispatching computer (EDC) respectively. RTMC, DMC and EDC are connected by a ring local area network. RTMC and DMC perform the functions of the level 2, while EDC performs that of the level 3.

(2) The local area computer system, which includes a data collection subsystem and three local dedicated ontrol subsystems and performs the functions of the level 1. RTMC can be connected with sixteen local area computers by a star local area network. The data collection subsystem has ten local area computers with the S—100 bus. An IBM personal computer in each control subsystem is considered as a local area computer. Other three local area computers are spares.

(3) The real-time baseband local area network[2], which can perform long-distance data transmission. The network partially meets the IEEE 802 standards. It has a physical layer and a data-link layer. The error control used parity check and cyclic redundancy check methods and a stop-and-wait automatic-repeat-request technique[3]. The data communication is in half-duplex, asynchronous, serial transmission mode. The real-time data communication is performed by the interrupt service subroutines allocated in the computers. These subroutines are initiated by the timer or the receiver data ready signal.

(4) The measurement and control mechanism, which convert different kinds of engineering signals to voltage signals of 0～5V, current signals of 0～10mA/4～20mA or digital signals and transfer control commands from computer to controlled process.

3.2 *Three Control Subsystems*

Of the overall energy consumption of the smeltery, the electricity is about 55%, while the coal and coke which is about 42% mainly used to generate gas. Therefore, the electrical load, rotary dryer and gas generator control subsystems are estabilished in the smeltery.

(1) The electrical load control subsystem considers a hierarchical configuration with two levels of computers[4]. An IBM personal computer is connected with ten industrial control computers in a star real-time network. Essentially, the IBM personal computer is an overall coordinator, and each of the ten industrial control computers is a local control unit controlling a transistor converter. The electrical load controlled by the 10 converters is about 70% of the overall electrical laod. The control objective is to guarantee that the overall electrical load should follow a given value. The overall coordinator coordinates the ten local control units to achieve the control objective. A dynamic coordination algorithm based on a weighting average rule is used to the subsystem design. The control objective can be expressed as

$$\|P_G - P\| < \mu \qquad (1)$$

where $\mu > 0$ is a given number, P_G and P are the given and output power vectors respectively. The constraint condition is

$$I \in [I_L, I_H] \quad (2)$$

where I_L, I_H and I are the minimum allowable current, rating current and output current vectors of the converters. Using the algorithm, the output vector I_G of the coordinator can be obtained. For each local control unit, the control objective is

$$\min J = \min\| I_G + I_P - I\| \quad (3)$$

where I_P is a preset value vector. It is shown that the utilizatioon factor is over 99% and the peak load is controlled to within 100.5% of the given value.

(2) The rotary dryer control subsystem has a two-level distributed structure with an IBM personal computer and twelve 761 series single station controllers[5]. A temperature field control scheme is used to keep a proper temperature distribution in the dryer. It can be implemented by suction pressure control, cascade control of the temperature and gas flow, and oxygen percentage control used PI, PID and P algorithms respectively. Each control loop is realized in a 761 controller. The IBM personal computer is a coordinator to coordinate the twelve 761 controllers for four dryers. It is shown that the suction pressure at the dryer tail can control in $-6 \sim -10$Pa, the percentage of oxygen in the smoke is less than 10% and the error of the temperature at the dryer tail is within $\pm 1\%$ of the given values, so that the gas consumption is reduced by over 34.7% compared with the manual control.

(3) The gas generator control subsystem uses a hierarchical structure with an IBM personal computer and an A_2 series programmable controllers[6]. For each gas generator, a mathematical mode for adding coal and discharging slag is obtained by the law of constant substance summation and exit pressure, saturation temperature and steam dome level control loops are estabilished by Bang-Bang, PI and PID algorithms. The A_2 programmable controller performs the direct digital control for six gas generators. The IBM personal computer performs the coordination of the exit pressures of the six gas generators, monitor of the process perameters and modification of the given values. It is shown that the gas calorific value and aerogenic effectiveness is respectively improved by over 3.87% and 1.37% than the manual control.

3.3 *Software Design*

The design of the applied software is based on modular programming and distributed technique. The energy database is designed by using the relational data mode and stores all energy information.

(1) The applied software is designed as a concentric ring structure with disk operating system, host run file, function run file and man-machine interface layers. Three host run files and various function run files were designed according to the tasks stipulated in advance. These run files can be run independently on the disk operating system. Each function run file can be executed to complete the associated function by the host run file. Only a host run file and a function run file reside in RAM at any time.

(2) All the energy database files are classified as data, remark, index, form and memory variable files. The completeness of the energy information is guaranteed by monitoring the execution of all the function run files and refusing or correcting the error operations for the energy information. A redundancy technique is used for the failure recover of the energy database.

3.4 *Energy Dispatching and Planning*

Based on expert systems technology and management science, a energy dispatching and planning expert system can be designed to provide reasons and tacties of optimally dispatching energy and perform dynamic plan of energy and production[6]. This is relative to administrative management and marke‹ of energy and product. The expert system makes the effective and satisfactory operation of the dispatching of the electrical load, drying process and gas generation possible.

4 CONCLUSIONS

The hierarachical model proposed in this paper is suitable to the energy management and control for the nonferrous metals indutry and can be implemented by computers and distributed structure. The distributed computer energy management and control system met the practical requirements of the smeltery. It has been shown that the technology applied in the system design are successful.

REFERENCES

1 Kaya, A *et al.* Automatica, 1983, 19(2): 111—130.

2 Wu, M *et al.* Metallurgical Industry Automation. 1992, 16(4): 23—28.

3 Bartee, T C. Data Communications, Networks, and Systems. Indianapolis: Howard W Sams & Co, Inc, 1985.

4 Shen, D Y *et al.* Metallurgical Industry Automation. 1990, 14(5): 27—31.

5 Wu, M *et al.* Journal CSIMM. 1993, 24(4): 477—482.

6 Wu, M *et al.* Automation: Theory, Technology and Applications. Changsha: CSUT Press, 1993.

(*From page 97*)

120 Let the approximate coordinates of Pi and Pj be (0, 0) and (S_1, 0) respectively

130 DO ! Infer the supposed approximate coordinates of each point

140 FOR I=1 TO PP ! Loop by points(PP is the total number of points)

150 FOR J=ZR(I) TO ZR(I+1)-1 ! Loop by bearings on point I

160 IF (the supposed coordinates of point I and the supposed azimuth angle in its zero bearing are all known)
AND (the observed value in bearing J>0)
AND (the distance from point I to sighting point in bearing J is known)
AND (the supposed coordinates of sighting point in bearing J is unknown) THEN

170 Infer the supposed coordinates from point I to sighting point in bearing J by traversing method

180 ELSEIF (when point I, its sighting points in bearing J and in bearing J + 1 form a triangle)
AND (the supposed approximate coordinates of two vertexes in the triangle (say P1, P2) are known)
AND (the other vertex P3 is unknown) THEN

190 IF (there are two internal angles in the triangle whose absolute value>1) THEN

200 Infer the supposed coordinates of P3 by angle cotangant formula

210 ELSEIF S13 and S23 given THEN

220 Infer the supposed coordinates of P3 by side cotangent formula

230 END IF

240 END IF

250 NEXT J

260 NEXT I

270 LOOP UNTIL (the supposed coordinates of all the points in the network are known)

280 ! Find the final approximate coordinates of each point

290 IF (the number of given points are more than two) THEN

300 Calculate the rotation angle and scaling factor of coordinates from the difference between the true and supposed coordinates of points 1 & 2

310 ELSE

320 Find the start-end points of a given azimuth by it' s number of bearing

330 Calculate rotation angle of coordinates through the true and supposed azimuths of start and end points

340 Find the start-end points of a given side by its bearing number

350 Calculate the scaling factor through the true and supposed side lengths

360 END IF

370 Calculate the translation factor of coordinates through the difference between the true and supposed coordinates of point 1

380 Calculate the final approximate coordinaes of each point by rotation angle, scaling factor and translation factor of coordinates

390 END SUB