A Process Optimization System Used in Metallurgical Plants

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Abstract: The paper presents an integrated system designed for the agglomeration factory and cowper stove process optimization. The system is based on a RT-ARCH (Real Time ARCHitecture)[1], an architecture of software tools used in process control.

Keywords: Industrial application, technological process, PLC.

Description of Technological Processes

Agglomeration Factory

The raw- materials used in the technological process are iron ore, coke, limestone and dolomite. The output at the agglomeration factory is exclusively destined for feeding blast furnaces. The agglomeration factory is composed of the following technological fluxes: measuring station, agglomeration machine, and sorting and dispatching devices.

Iron ore, coke, limestone, the returning agglomerate from sorting, and iron offal, are piled in the containers of measuring station. The raw- materials are unloaded from containers through running belts conducted by programmable logic controllers (PLC) which receive signals from the electronic measuring devices. Then, they are homogenized and sent to the agglomeration machine.

The agglomeration machine does the pyro-metallurgical process of sintering, the resulting agglomerate being riddled at high temperature, then cooled, sorted and dispatched to blast furnaces. The agglomerate is sifted and sorted by size and granulation.

Cowper Stove

Cowper stoves (pre-heaters) are those which heat the air up to 1100 ^{0}C and supply this to a blast furnace. As a general rule there are four pre-heaters. Their focus is on where gaseous combustible burns. It is the refractory cellular structure of the body of the pre-heater that makes the warmth given by burning gases not dissipate.

A pre-heater has two work phases:

- A heating period, when the refractory structure is heated at high temperature by burning the gaseous combustible in the focus
- A blowing period, in which the cold air circulated contrary to the gases burnt in the recent period, takes over the heat accumulated by the refractor in the heating period

The Information Structure of the System

The information system is mainly designed for the acquisition of data and technical parameters and for operative information supply to the process control, for the operation and maintenance of the equipment. The entry data are digital or analog signals received from transducers via process interface. As a result of data processing, the computing system produces the exit data, either analog or numerical, that can be used for controlling, adjusting, or can be displayed on video terminals.

The system has a database for data and programs on the mass memory (one or more magnetic hard disks).

The following information is received by the automation system:

- From electrical powering it receives on-line/off-line information about the following events: starting / stopping the devices; device mode (idle / active); alarms;

damages and types of damages; existence of power and controlling tensions

- From weighing machines in containers, on the running belt, or on the measuring devices, the system receives analog or digital signals on mode; damage; kind of material; throughput of transported or measured material; quantity transported or measured; place of stocking or transporting; proportion of different components of material.

- From measuring, controlling and adjusting devices, the system will receive analog or digital signals on temperatures at different points of thermal processing; throughputs of water and gas; dynamical analysis of different gases; equipments' performance

- From the upper hierarchical level, the system receives data on production planning; raw -materials supply programs; material, fuels and energy consumption; maintenance programs

Description of the Techniques

Typically, classical control techniques use analog PID (PI, filtered PID) controllers, or on-line/off-line controllers for slower processes. Controllers are used in structures like:

- Simple adjusting with imposed reference

- Cascade adjusting

- Combined adjusting by perturbation and reference

These types of controllers have the advantage of being easy to implement, but quite often their parameters are fixed. That is why classical control structures can only be used with those subsystems of technological installation that have very well- defined models, or modest control requirements.

From all the diverse modern control techniques we have chosen to implement some algorithms by computer programs. This implementation proves great flexibility: the data of the program that contains the adjusting parameters, are easy to modify.

Hardware and Software Architecture

The hardware platform used as a support of the control programs is a personal computer with a Pentium 100 MHz processor, 32 Mb RAM, 64 bits video graphic accelerator, SCSI 1Gb HDD, data acquisition card, one multiplex for 16 serial ports and a network of 16 PLC-s. On this machine we have used Windows NT operating system. This system offers multitasking facilities for parallel managing of such aspects as data acquisition, data transmission, adjusting and display. Through multitasking we could manage more control loops on the same computer even though some of the processes are controlled only by PLCs.

We have used Visual C++ 4.0 as a development platform , because it can compile programs for Windows NT operating system and has the following facilities:

- Permits creation of separate threads with different adjusting algorithms for each of the processes.

- Offers communication methods inter-threads for data transfer between data acquisition processes and controlling processes. Communications are made using message boxes and critical sections.

- Permits realization of communication modules in a TCP/IP network. That makes it possible to implement a hierarchical architecture.

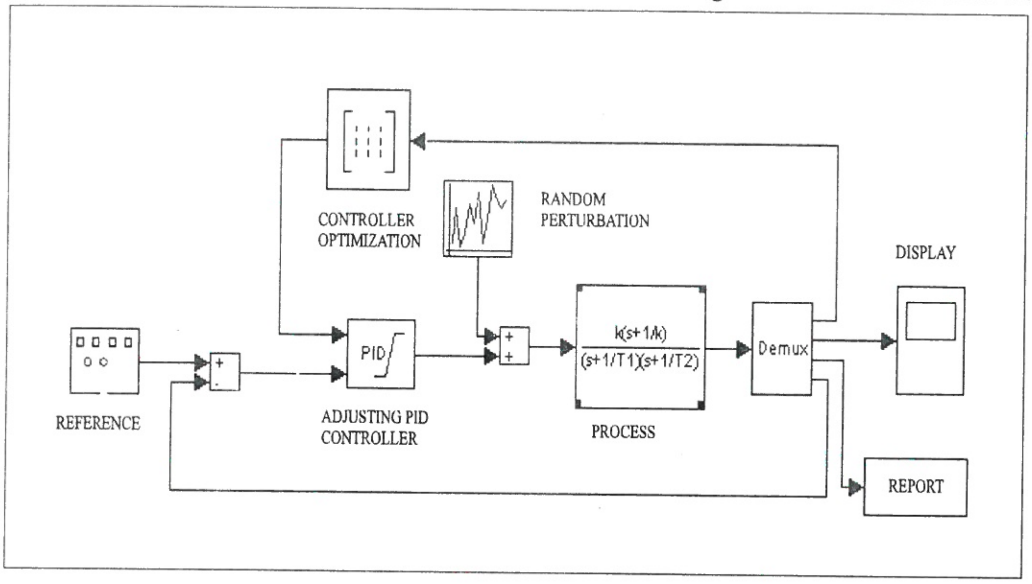
- Offers the possibility of creating a user-friendly interface to the product, under Windows environment.

The only disadvantage of this platform is that it has no dedicated functions for performing complicated mathematical calculi needed in adjusting algorithms. We had to write them ourselves.

A process computer is placed in the control room of the technological installation because it must be protected from vibrations and from the environment of the technological process.

Process Optimization

Our optimization problem is "given a dynamic system (S) that evolves on a finite time interval $[T_0...T_f]$ and the performance index J (u) it is required a command that minimizes J". In this standard formulation there are no restrictions, but it follows a movement in the states space for minimum energy consumption. Using the computer we have chosen dynamic optimization, that relies on the idea of finding a procedure for generating a "relaxing" array defined by the following condition:



X1, X2, X3, ...Xn, so that $f(X1) \geq f(X2) \geq f(X3) \geq \ldots$ with the property that if $Xk \rightarrow X$, then $f(Xk) \rightarrow f(X)$, where X is the extreme value of the objective function in a specific domain.

The relaxing arrays generating procedure has two components:

- Choose the descending direction of the function with the modified Newton method. This is a gradient method implying successive approximations of the function.
- Determine the step on the descending direction.

Control System Functions At the Agglomeration Factory

The automation system works in a collecting-processing way, interfering with and conducting the controlling processes. The system performs the following functions:

- Supervision of technological equipments and devices
- Displaying and printing of any damage that may occur, showing the moment of occurrence, the type and place of the damage
- Displaying and printing of the alarms at the moment of their occurrence
- Showing the entries to and exits from the programmable logic controllers for debugging any anomaly or damage
- Controlling the measuring equipments and supervising the process of combining raw-materials
- On demand displaying of the technological process parameters
- Calculating the consumption of raw-materials by sorts, indicating norms of consuming for combustibles and electrical energy
- On demand, transmitting data about the level of production, the structure of consumption, etc., to the upper hierarchical level

Some of the technological installation subsystems are variable in time due to the action of stochastic perturbations. That determines large variations of the parameters of the attached mathematical model, but, fortunately, the model structure keeps the same.

Control is exerted at the level of central computer, and also at the level of the PLCs. We have used a hybrid adjusting method, i.e. some adjusting loops are implemented with classical algorithms (PI, PID), and the others are adaptive algorithms.

The system is composed of:

- Classical algorithms running on the PLC-s that have also implemented data acquisition modules, and analog and digital command modules. Programs are written in the PLC's language (PL 7-2).

- Controlling algorithms implemented with process computer. Some of them are typical numerical algorithms, and the others are adaptive control algorithms.

Control System Functions At the Cowper Stove

The primary objective of numerical controlling of pre-heaters is optimization of the technological process. This optimization brings about high efficiency and combustible saving. The computer controls and effectively optimizes the technological process. Intelligent control of the process exerts at the level of process computer. It carries out the following functions:

- Compute the quantity of warmth required for heating pre-heaters. Optimization of the technological process imposes an exact correlation between the quantity of warmth required for heating and the quantity of warmth taken by the air blown into the furnace. This correlation can determine a minimum combustible consumption for heating. The optimization algorithm is:

$$W = \int_{t=0}^{t=t_s} Q_w(t)dt$$

Where Q_w is a thermodynamic equation depending on the quantity of warmth taken by the air blown during a blowing period t_s.

- Computing the caloric power of the combustible gaseous mixture. Pre-heaters are supplied with a mixture of gases in different proportions. It is required to calculate the minimum debit of mixture, depending on the caloric power of components.

The relation is: $F_b = \dfrac{Q_W}{H}$, where:

F_b is the gaseous debit
H is the caloric power of the mixture of gases
Q_W is the quantity of warmth

- Computing the debit of air required. For a complete burning, the proportion of gaseous combustible mixture and air in the focus must be optimal. This value is calculated starting from the quantity of air required by any of the components of the combustible mixture.

The relation of caiculus is:

$$F_a = \frac{k_1F_1 + k_2F_2}{F_1 + F_2} F_b, \text{ where:}$$

F_a is the throughput of air
F_b is the debit of combustible mixture
k_1, k_2 are variable coefficients
F_1 is the throughput of the first component of the combustible mixture
F_2 is the throughput of the second component of the combustible mixture

Depending on the values obtained, the computer commands and adjusts the debits of gaseous combustible and air, and the time between the two work phases of the pre-heaters.

Conclusions

An implementation of this system in Romanian metallurgical plants will have the following advantages: high efficiency and combustible saving, limited efforts for developing a new application in a short period of time, and high performance of the system in solving the application requirements.

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