AUTOMATION OF THE BLAST FURNACE

The Khwarzimic Science Society

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Title:

Process and Control of BF Process
(Computer Integrated Extraction)

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Introduction:

The electronic and computer revolution lead to the automation of many mission critical manufacturing processes, which resulted in better quality management and close specification control along with a considerable decrease in the cost per piece of the product. This also lead to solve the problem of worker strikes which were quite common in the first world countries due to very strong worker unions. The automation also saved many lives by replacing humans in many harmful environments. The first era of the automation evolution was the use of remotely human operated robots and machines which enabled humans to control the factory by sitting in the control room. The next era was the Computer Integrated Manufacturing (CIM) and Computer Aided Manufacturing which allowed the machines to manufacture the required product from drawings and the only staff required was/is maintainace staff and designers. The new era is named as flexible manufacturing which is an extension of CIM/CAM but the difference is that many different products can be made from the same machinery at the same time, thus reducing the cost per part to ground.

In these papers an approach to CIM is used and I named it Computer Integrated Extraction (CIE). Currently, the blast furnace at Karachi Steel Mill is already automated but the system lacks complete computer integration and still requires operators with Metallurgy and Computer experience. My aim in these papers is to propose some guide lines which can be used in blast furnace to run it on auto-pilot or autonomous computer only system, which will no longer be dependent upon operator skill. Currently, the furnace runs on three shifts on 24-hours continous cycle and it is over employed. The proposed system might help down size the un-necessary staff and may help to make Karachi Steel Mill profitable.

Electronic Sensors and Control:

The main variables in the blast furnace which need to be sensed by the master computer for comprehensive sensing and control are:

1. Composition.
2. Sizing or Screening.
3. Temperature.
4. Pressure.
5. Voltage. (only in Electrical Generators)
6. Ampere. (only in Electrical Generators)
7. Misc. Variables and Sensing.

Next are the electro-mechnical devices to enable complete control of master computer, these devices may come in the following categories:

1. Effectors / Acuators to replace humans in operations, like openning and closing of doors in Coke ovens, controling double bell charging system, etc.

2. Robotic Manupulators to replace human arms in operations like picking samples, tranfering materials from Automated Ground Vehicles, carrying molten metal in ladle, etc.

3. Automated / Semi-Automated Ground Vehicle to transport mterials and products from one processto another, like carrying sintered charge from sinter plant to blast furnace charging mechanism.

4. Interfacing Devices to integrate existing control devices with computer, like integration of oxygen valve in the converter process.

Next is the computer related machines to control the whole operations, this includes:

1. Personal and Mainframe Computers, which may be divided as:
   (a). Master Control Computers.
   (b). Terminals for Data Entry and Remote Process Control.
   (c). Dedicated computers like Controller of Spectrometer and Industrial Screens.
   (d). Microcontrollers for programable logic control of equipment like thermocouples, pressure transducers, etc.

2. LAN Based high speed computer network.
3. Microcontroller-PLC (Programable Logic Control) network for Microcontroller integration with main computers.
4. Interface Cards and Circuits for the integration of existing machine controls and sensors with main computers.

Sensors

1. Composition Analysis:

Composition analysis is one of the main mission critical variables to guarantee troubleless BF Operation and Product Composition. In a typical steel product from a BF operation the main critical elements are:

1. Carbon. (Fe_3C, Solid Solution, Free Form)
2. Sulphur. (MnS, FeS, etc.)
3. Phosphorus. (Free Form, etc.)
4. Manganese. (Free Form, MnS)
5. Silicon. (Solid Solution, Free Form, Oxide)

And some other important elements are:

1. Chromium.
2. Molybdenum.
3. Nickel.
4. Aluminum.
5. Titanium.
6. As.
7. Bismuth.
8. Cobolt.
9. Copper.
10. Nitrogen.
11. Niobium.
12. Vanadium.
13. Lead.
14. Rare Earth Metals.
15. Antimony.
16. Zirconium.
17. Oxygen.
18. Hydrogen.

Some typical products and stages which are necessary to analize are:

Materials **Elements required** **Analysis Time**

Products

Carbon Steels
Liquid C, P, S, Si, Mn, O, H, N Less than a minute
Solid 1-5 minutes (Max)

Alloy Steels
Liquid C, P, S, Si, Mn, Mo, Ni, Cr, O, H Less than a minute
Solid 1-5 minutes (Max)

Special Steels
Liquid C, P, S, Si, Mn, Mo, Ni, Cr, O, H, Less than a minute
Solid Co, N, Pb, V, Sb, As, Bi 1-5 minutes (Max)

Slags
Solid Fe2O3, Fe, SiO2, MnO, CaO, Al2O3, MgO In some steel plants less than minute; Normally 1-5 minutes.

Ores
Solid (granular) Fe, Si, Mn, Ca, Al 4-10 minutes (used to pay mine owners and ore vendors) Also to check on blending plant operation.

Coke
Solid C, S, O, H2O, N2, etc. Depends upon technique

Pig Iron
(hot metal)
Liquid P, S, Mn, Al, Si, C 1-5 minutes

Refractories
Brittle Solid Al, Mg (as oxides) Si, Ca, etc. 5-10 minutes

Sinters
Hard, Brittle Solid Fe, P, S, Mn, Al, Si, CaO, C 1-5 minutes

Ferro Alloys
Hard, Brittle Solid Fe, Mn, Ni, Co Cr 1-5 minutes

Pollutants
Usually liquids NH4OH, As, Cyanides (CN), Fluorides (F), CO 1-5 minutes

Gaseous

Blast Furnace
Off-take CO, CO2, etc. 10 seconds
In-Take O2, CO2, H2O Vapours, etc. (vital fo safety)

Steel Convertor
Input gase O2
Output gases CO, CO2, FeO, etc.

One of the main applications of intermediate-stage analysis is to diagnose the faults in steelmaking practice via slag analysis. Much information can be deduced from this source, a typical analysis being as follows:

FexOy	17-18%
CaO	43%
SiO2	14%
P2O5	1.1-1.5%
S	0.1%
MgO	10%
Al2O3	6%

Here if the iron oxide content is low then overr-oxidation is present, due to faulty charge calculations or incorrect hot metal analysis. A high FexOy indicates possibly faulty lance practice. The lime and silica levels are affected by flux addition practice, which may be faulty. The P2O5 level is sensitive to either:

1. High Temperature at turn down.
2. Low state of oidation of slag, i.e. high turndown carbon.
3. Low slag iron (<14%), low CaO level in slag or badly fluxed slag.

Sulphur levels are also critical indications of practice in oxygen steel making. The ratio between sulphur in slag to sulphur in steel should be between 5 and 8. If it is high 8-15 then the extra sulphur in the slag must be traced. If it is low then poor fluxing is indicated , with high blast-furnace slag carry-over as an alternative explanation.

Instruments used in the analysis are:

Method of Analysis	**Materials to be analyzed**	**Automation Method**
Optical Emission	(a). Crude Steel (b). Products	Stand-alone computer integrated with main network.
X-Ray Fluorescence	(a). Slags (b). Sinters	Stand-alone computer integrated with main network.
Inert Gas Fusion	Steels	Terminal attached to the main network.
Plasma Method	Liquids	Stand-alone computer integrated with main network.
Ion-selective electrods	Liquids	Stand-alone computer integrated with main network.
Mass Spectrometry	Off-take gases	Stand-alone computer integrated with main network.
Neutron activation	solid steel	Stand-alone computer integrated with main network.
Hight Temp. Combustion	S and C in Steel	Stand-alone computer integrated with main network.

A brief desciption of the methods is:

- **Optical Emission:**

A spark or arc is struck to a solid sample. The light emitted is then wavelengthdispersed by a grating into spectral lines whose intensities ae compared with those frrom a reference sample. The intensity of radiant emission at selected wavelengths is measured by an array of photomultiplierr tubes. Signal outputs are compared to percentage composition using computer. The computer will be connected to the Master Computer by a LAN (Local Area Networrk) through which it will send the percentage composition to the Master Computer.

- **X-ray methods-energy dispersed:**

This technique is the same as the wavelength dispersed x-ray method except that the emitted fluorescent radiation is detected by doped semiconductor whose output is proportional to the wavelength (energy) of the X-ray. Again, composition is derived by comparison with standard sample and calculated on computer, which will send the pecentage composition to the Master Computer by LAN.

- **Atomic absorption:**

The sample in liquid form is passed into a flame, where atomic species are formed. Radiation from a narrow band source is passed through the flame where radiation, characteristic of the element to be determined, is absorbed. Measurement of the absorption coefficient of the flame determines the concentation of the element. The calculated percentage composition calculated by an attached computer, is sent to main computer by LAN.

- **Fusion analysis of gases:**

In this basic method of the detemination of oxygen in steels, the solid sample is fused in a graphite crucible either under vacuum or in argon atmosphere. Oxides present in the sample are reduced to form carbon monoxide which is measured typically by infrra-red absorption. Nitrides present in the sample are decomposed during the fusion process. N2 is usually measured by a volumetric process after removal of CO and H2. Hydrogen can also be determined typically by its thermal conductivity afte the gases have been extracted from the liquid sample. Palladium is used to isolate hydrogen from the extracted gas mixture. This process is rather difficult to integrate with the main computer network. However this can be done by using a terminal to the main network.

- **Plasma Method:**

The liquid is first nebulized and then passed into an inductively coupled plasma. Then in these methods the vapour of a liquid to be analyzed, or a gas, passes thrrough a coil in which a radio-frequency field is created, so exciting emission spectra characteristic of the vapour or gas. The composition of the gas (or vapour) is then easily found using a conventional spectrometer attached with a computer. The data is then sent to Master Computer by LAN.

- **Ion-selective electrodes:**

It has been found that simple electrochemical cells can be formed in ions in solution can be detemined without, in many cases, interference from other ions. A simple emf measurement gives a result in terms of ion concentation, which can be converted into percentage composition and sent to master computer.

- **Mass Spectroscopy:**

A gas can easily be analyzed by ionizing its constituents and passing the ions through a magnetic field. As the radius of the path followed by the ions is a fuction of their mass, slits can be placed to isolate the ions of interest. This method is particularly useful for the analysis of waste gases from the furnaces for CO, CO2, N2 and H2. The result calculated by the attached computer is sent to master computer by LAN.

- **Neutron Activation:**

In this elegant technique, neutron bombardment of a solid sample produces an unstable isotope, which decays, emitting gamma rays. Counting the resulting gamma rays results in a determination of the element in question provided that only the right energy gamma rays produced by inelastic scatteing of the incident neutrrons.

Neutron activation has been used for the detemination of oxygen, with the prompt gamma mehod being usefull for Si determination. However, neutron activation has made little or no impact on the steel industry despite intense effort in the 1960s.

2. Sizing and screening:

Sizing and screening is required at raw material input and sinter plant to let the desired sized particles pass and reject the remaining. This can simply be achieved by using industrial screens, which start from small diameter screens to large diameter screens in many steps, electronic weighing machines permanently manufactured at the bottom of each screen can be used to measure the weight retained in each screen and this data may be digitized and put to an attached computer, which will feed the data to the master computer by LAN. The attached computer besides sending the weights retained, can also be used to control robotic arms to spread the particles uniformly on the screens and to remove particles from the screen. The robotic arms can also be replaced by mechanical counterparts for cost-reduction.

3. Temperature Measurement:

Temperature is the main mission critical variable especially in blast furnace, which should be measured at all costs. The temperature in the blast furnace gives following information:

1. Combustion: The extent of combustion of coke and oxygen in air can be directly known by looking at the temperature of the blast furnace.

2. Reactions and Processes: The temperature, especially the temperature distribution of the entire blast furnace gives an idea of the extent of reactions and processes occuring in the furnace.

3. Condition of Refractory Bricks: The condition of the refractory bricks can be judged from the comparison of the temperature of outer shell and internal temperature.

Numerous devices can be used to determine the temperature of various stages in steel making, some of the most common methods are:

(i). Optical Pyrometer:

The temperature results in the emission of radiations of special wavelengths, an optical pyrometer is device used to measure the intensity of these special radiations by semiconductor photo sensors and display them as the temperature on the display. The are usually gun shaped devices and can be used to measure the desired temperature without any contact with the hot material. Special Computer integrated optical pyrometers are also comming into market which can be placed on fixed positions and digitized to connect with a computer. However, they are mostly used as portable units to inspect the temperature.

(ii). Thermal / IR Camera Systems:

Thermal / IR Cameras measuring light usually in 3 to 8 micrometer wavelength by a thermally stable cooled Camera Array. It measures the near infra-red

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light emitted from hot objects by black-body radiation. These cameras usually contains built in computers or external portable computers to make temperature distribution diagrams in real time and also provide point temperatures at selected points without any physical contact. Thermal Graphs or thermograms are usually obtained from these cameras. The are also used to detect the thermal gaps in the furnace due to possible wear-off or damage of the furnace linning. This is very expensive equipment, extremely useful and is used in the inspection of the furnace for refractory damages and is quite commonly employed during the errection of the furnace by manufacturer..

(iii). Thermo-couples:

Thermo-couples are formed by joining two dissimilar metallic wires and measuring the emf in the wires by keeping one joint at reference temperature and the other at temperature to be measured. They are the most widely used temperature measurement tools in metallurgy, due to their easy operation, high accuracy, high temperature stability and rugged use.

Depending upon the metals used, the developed voltage increases between 7 and 75 micro-volt for each degree celcius increase in temperature. J-Thermocouple a junction between iron and constantan is uesd to measure between -184 to 760 degree celcius. And C.A. Junction of Platinum and its alloy and 13% Rodium has a usefull range of 0 to 1600 degree celcius.

In Cold Junction Compensation, a reference junction made of the same metals must be connected in series with the junction being used to make measurement. The reference junction is connected in the reverse direction from the measuring junction. This is done so that the output connecting wires are both constantan. The thermocouples are formed by connecting these wires to the copper wires going to the amplifier will then cancel out. The input voltage to the amplifier will be the difference between the voltages across the two thermocouples. If we simply amplify this voltage, however, there is a problem if the temperature of both thermocouples is changing. The problem is that it is impossible to tell that which thermocouple caused a change in output voltage.

As a solution an electronic circuit is used to compensate for changes in temperature of the reference junction. AD590 shown here produces a current proportional to its temperature. The AD590 is attached to the reference thermocouple so that they are both at the same temperature. The current from the AD590, when passed through the resister network, produces a voltage which compensates for changes in the reference thermocouple with temperature. The signal to the amplifier then is proportional only in changes in the sensor thermocouple.

Another problem is that the voltage does not change linearly with temperature change. This can be corrected with analog circuitary which changes gain of the amplifier according to the value of the signal. However, in digital application correction can easily be done using a lookup table in ROM or Program Memory of the Microcontroller and an analog to digital converter to convert the analog value to the digital one. The digital value is then used as a pointerr to a ROM location which contains the correct temperature for that reading.

(iv). Semiconductor Temperature Sensors:

Semiconductor sensors like National's LM35 can be used to measure lower temperatures in the range of -55 to 150 degree celcius. The voltage increases by 10mV for each degree celcius rise in temperature. The analog to digital converter usually of operational amplifiers and the output of LM35 is adjusted to 0V for 0 degree celcius. But due to their lower temperature measuring capability they are not employed in metallurgy.

(v). Thermister and RTDs:

Resistance Temperature Detectors and thermisters are also commonly used temperature sensors. RTD's have capability to measure in the range of -250 to 850 degree celcius. These RTD's and Thermisters can be encapsulated in refractory bricks due to their low cost. These bricks may be used to line the othermost layer of the furnace to give precise readings. The resistance is converted into voltage change and digitized by analog to digital converter.

The Thermocouples or RTD's may be connected to microcontrollers (Like AT89C5X) via A/D converters or directly with microcontrollers with builtin A/D Converters. The microcontrollers will be connected to the server microcontroller by two wires TXD and RXD besides two power wires. The Server Microcontroller will be connected with an external computer connected to Master Computer by LAN. The data from each microcontroller can be accessed by addressing each microcontroller seperately, thus exploiting serial interrupt feature of Atmel 8051- Architecture.

3. Pressure Measurement:

Pressure measurement of off-take gases, blast gases and internal blast furnace pressure is very important variable.

(i). Strain Gages and Load Cells:

A strain gage is a small resistor whose value changes whens its length is changed. It may be made of thin wire, thin foil or semi-conductor material. These are used to convert mechanical pressure guages already installed in the Off-Take Gas Processing Plant into analog electronic signals, whcih in turn are converted to digtal signals by analog to digital converter and integrated with microcontroller.

(ii). Linear Variable Differential Transformers:

In this method the core of the transformer is moveable and the change in the voltage of secondary coil is exploited to measure the temperature. A fixed voltage of known value and 20Khz frequency is fed at primary coil as AC Excitation Signal. The secondary coils are actually two coils and opposite ends of each are connected with each other, while the remaining two are used as output. The output voltage is converted into digital signal by special AC interface digitizer and is fed to microcontroller.

(iii). Potentiometers:

Potentiometers can be used with pressure guages to give a reading of pressure in a linear change in resistance, which can be converted into digital signal by analog to digital converter and fed to microcontroller.

5. Misc. Sensors:

Varius other sensors can be used in Steel Making to detect various variables which are important for complete automation are used. Some of them are:

(i). Height of Burden in Stack:

Height of burden in stack is an important factor and can be detected by a variety of methods. One of the most easly and low cost method is the use of laser beam to detect the height. The laser may enter the stack from a quatz window on one side and leave the stack to be detected from another quartz window on the opposite side. A pulsing laser of UV band may be employed to prevent it from being interfered by the light produced by the heat in the stack. More than one laser beams can be provided at different heights to enable the computers to detect exact height.

Another alternative which is less affected by the presence of dust particles is the use of ultra-sound instead of laser. An ultra-sound transducer will send a signal from its diaphram on the top of the stack and below the double bell loading system and receive the sound waves after being reflected by burden surface and by noting the time taken to return the sound waves will yeild in the exact burden height. The only disadvantage is to make an ultra-sound system stable enough to operate at 200 to 600 degree celcius.

An indirect way, however, is to look at the thermal profile of the blast furnace as detected by the arrays of temperature sensors. The specific heat of the burden is greater than that of the atmosphere above it and at the surface of the burden there is a rapid decrease in temperature in the thermal profile. This method still requires atleast one laser sensor at maximum possible height of the burden which it may be harmful, to provide an additional safety as there may be false readings by thermal profile.

(ii). Gas flow detectors:

The velocity of the in-take gas or hot blast is an important factor and may be measured by the introduction of a small turbine connected to a small low power generator just before tuyers. The voltage generated by the generator may be converted into digital data by analog to digital converter and fed to microcontroller or computer.

Control Devices

1. Effetors / Actuators:

Effectors or Actuators provide translatory motion and may be used in Blast Furnace operations like in opening and closing of bells in double bell charging system, Tilting Steel Converter, etc. There are numerous ways to make effectors / actuators, some of the common ones are:

(i). Mechanical Actuators:

Mechanical actuators are very common in robots and many industries where robots are being employed in one way or the other. They may be a threaded shaft connected to a high speed motor and shaft being fixed in a nut like arrangement. The nut arrangement will move in translatory motion on the rotatory motion of the shaft. A stepper motor may be used to drive the shaft to provide accurate control of the actuator length. Yet another alternative used in most of the CNC Machines is the servo control, in which a linear potentiometer connected with the nut to detect its location on the shaft, will be driving the servo circuit and the servo circuit will provide an accurate control of the motor according to the input signal provided by the microcontroller.

(ii). Pneumetic Actuators:

In pneumetic actuators air or gas is pumped into the actuator by a pump. Thee system can be understood by visualizing the actuator as an injection syring as used in medicine. When air is pumped into it from the opening the piston will move upward, thus making translatory motion and when it is removed the piston will move downwad. This mechanism can also be contolled by a servo control circuit and linear potentiometer.

(iii). Hydrolic Actuators:

This is same as pneumetic actuator, but the only difference is the use of water or oils instead of air for moving the piston. It is used for more heavy jobs where very powerfull force is required like in the tilting of steel converter.

2. Robotic Manupulators:

Robotic Manupulators are an essential part of automation installation, they required to replace human arms and perform much more powerfull and heavy jobs like transferring run-of-mine from thee conveyor belts to the crushers and grinders, lifting and moving crucible of molten metal, etc. The design and type of manupulator in automation is job specific and may require many books to cover this subject, however a brief overview of some of the commonly used devices to drive and sense is given below:

(i). Motors:

Motors are used to provide rotatory motion in various parts of the manipulator and drive other devices like Actuators, Pneumetic and Hydraulic Pumps, etc. There are different types of motors used depending upon their usage. High speed motors are used in mobile units to move robots and manipulators, etc. Stepper motors usually coupled with rotation sensors are widely used in operations where precise motion is required, but in modern automation applications they are largely replaced with servo motors which have built in sensors to guarantee its precise motion. A servo motor consists of a motor usually geared and coupled with a feedback potentiometer, which controls the oscillations of a square wave oscillator. A comparator compares the oscillations of this local oscillator and the control signal feeded externally, if the frequency of both signals is not same it will continue the motor to rotate untill both signals matches each other. Thus a precise position can be obtained by feeding an appropriate input pulse.

Servo Motors and Stepper motors both can be integrated with a microcontroller. To integrate a stepper motor simply connect four digital output of the microcontroller to the stepper motor through an open gate buffer as stepper motor requires large amount of current. In case of stepper motor a single digital output is connected to the servo motor, but this output and microcontroller should be fast enough to give pulses instead of static logic signals.

(ii). Actuators:

Actuators are used to provide translational motion and are usually of mechanical, peumetic and hydraulic type, depending upon the application and precision.

(iii). Sensors:

Sensors are the fundemental parts of all the manipulators and robots. They may range from simple potentiometers to fibre-optic pads. Simple potentiometer are usually used to detect the rotaional or translational position of the part. Pressure transducers and micro-switches are used in hand to detect the firm grasp of the hand on the job. Optical and Magnetic Tachometers are used to measure the speed of the rotation. In optical tachometer a beam is allowed to pass through a hole in a gear and each revolution results in passing of a beam of light to the photo sensors, which gives the speed by counting the number of beams per second. Optical beams are also used to detect precise position of the rotation in some advanced applications. Fibre-optic pads, which usually have a built in micro-computer are used to detect the bends, etc. in the manipulators, acting just like skin, but there use in robotics is very limited due to their high cost.

3. Automated / Semi-Automated Ground Vehicle:

Autmated Ground Vehicles may be used to transport raw material, products and samples from one section of the steel mill ro another. They usually consists of mobile units, sensors and autonomous computers. In steel mills the most common AGV's are the one that move on tracks or optical, magnetic or electric strips which are build on the floor of the mill. I personally recommend optical strips due to the ease of the replacement and low cost. In most cases a different color (which maye be fluorescent) is painted on the floor which acts as a guideline for the mobile unit of AGV which optical detection circuits. At reletively low cost installations, semi-automated ground vehicles are also found which are controlled externally by human beings sitting in a control room.

4. Interfacing Devices:

Various interfacing cards and circuits are used to integrate manually controlled equipment. These interfacing circuits usually require analog to digital converters and digital to analog converters. Operational amplifiers are used as ADCs and DACs and now there are some specialized micro-controllers which have built in ADCs and DACs and can be used to connect these analog devices to digital network. To connect digital equipment with computers micro-controllers or parallel ports are used. Micro-controllers connect to these devices by their parallel ports and connect to the Personel Computer with serial ports. Intel's 8255A is a programmable parallel port which can be used to in ISA-Slot Cards to integerate digital devices with Personel Computer. Similarly, Intel's 8251 is used to connect digital equipments on serial outputs to personel computer, normally used serial protocol in most of the industrial equipment is RS-232.

Computers:

1. Main Computers:

The Main computers may be Mac Machines, Unix Workstations, IBM Compatible Personnel Computers or Main Frames, depending upon the investment of the installation and application. In most cases IBM Compatible Computers or to be more accurate Intel Microchips based computers are low cost, easy to use and more up-to-date. But some special applications might require some properties which are only found on Mac Machines, Unix Workstations or Main Frames. The selection of an appropriate operating system also varies from one installation to another. A brief review of some of the commonly found operating systems in automation applications is as follows:

(i). Microsoft's Windows Family:

Microsoft's Windows Family includes Windows 95-98 (a combination of DOS Kernel and Windows GUI), Windows NT (Windows New Technology Kernel) and Windows 2000 (an upgrade of both Windows 98 and Windows NT). These operating systems especially Windows 95-98 are easy to use, user friendly and graphical environments, which from the performance view point is a drawback as too many system resources are wasted on graphics but very little is usefully applied to control automation equipment. However, they are always prefered by end users and are used as terminal to inspect or view what is happening in the Automation Conputers.

Windows NT and Windows 2000 on the other hand is bit more usefull as it serves as a server of a network of computers and at the same time is user friendly and reletively easy to operate. But its eye poping graphics are also a threat to its lower performance from the hardware point of view. But it is being prefered by many industrialists in their automation project as Windows NT operators are easy to find and can be put on reletively lower wages. Also the upgrade of the system is inexpensive and can be done without even hiring a team of software designes. Software development is also inexpensive on Microsoft based operating systems due to their wide spread availablility.

(ii). MacOS:

MacOS is another graphical windows based operating system which runs only on Macintosh computers. The common networking protocol is the appletalk. The system is very efficient in terms of graphics use as in most models there is seperate hardware to deal with the graphics and thus comparitivily more powerful resources can be provided to the automation equipment. However, its software developers are very hard to find and also its cost and upgrade is a big threat to its use in automation. However, it is mostly used where virtual reality and 3D graphics are required.

(iii). Unix:

Unix unlike Windows and MacOS is 128-bit operating system and most of the work can be performed on non-graphic interface which allows better performance from the hardware point of view. The only hurdle is its cost, availability and upgrading cost. The software developers are also not hard to find but in Microsoft dominated countries like Pakistan, India they are bit hard to find and costly. However, the stability of the Unix machines persues industrialists to choose this for their automation needs. In some examples the Unix Systems are running from many years without shutting down, Internet is the best example which is about 80-90% of Unix Servers.

(iv). Linux:

Linux is a unix clone developed and distributed free for mostly Intel based computers. It is very much like Unix, but the good point about it is that its source code is freely available and it can be customized to an automation process thus ranking it far above the other operating systems in industry. It is highly stable, just like Unix, the main hurdle which may be found is the higher cost of the development of a customized kernel and lack of user friendly environment. But this all is changing with the introduction of RedHat, Debian, BeOS and other commercial clones which makes it easy to customize and user friendly. X Window a windows based GUI software can be run on linux to make it GUI just like MacOS and Microsoft Windows.

(v). Solaris:

Solaris is introduced by Sun Microsomputers and has been it commercial trade mark ever since. In Pakistan its use by PAKNET an internet division of PTCL have given an example of its high stability and resistance to intense traffice without any failure. It is usually a non-graphical OS which allows it to provide better power to automation process. Very recently it was announced by Sun Microcomputers that its source code is open for industry to be used and customized. This openned new frontiers for its use in Automation.

2. Micro-controller:

Micro-controller is perhaps the most important device which actually made automation possible. In mosr micro-controllers the microprocessor, RAM, ROM, Parallel Ports and Serial Ports are all incorporated on a single microchip, thus enabling it to be used in automation very easily. Texas Instrument's is using Intel's 8051-family microprocessors with built in ROM, RAM, Parallel Ports, Serial Ports and even Analog to Digital Converters, a specialized microchip can be found from its long list to suite the requirement. However, its lack of availability and reletively higher cost in Pakistan is a threat towards its use. Another company Atmel has introduced it micro-controller line including AT89C51(costs around Rs.125/-) , AT89C52 (costs around Rs.250/-) and AT89C55 (costs around Rs.450/-). All these contain 12MHz to 24MHz 8051 Microprocessor, Flash memory (electronically programable) instead of conventional ROM, limited RAM, Parallel Ports usually four, Serial Ports, Interrupt and Timer Counter. AT89CX051 is with built in analog to digital converter, thus requiring minimum circuitary in analog interfacing. However, AT89CX051 is not available in our local market, but can easily be imported from international market at very low cost. Some devices used in Atmel microchips are reviewed as follows:

(i). Microprocessor:

Each of the Atmel Micro-controllers use Intel's 8051-Familt Microprocessor which can be operated at frequencies 12MHz to upto 24MHz, which are quite sufficient for automation applications. The 8051-Assembly language is vey much like 8086-Assembly which is taught in many Universities, but lot more easier. Some common difference are:

1. OUT, INP and MOV statements are merged into a single MOV statement, which may be used to address memory, ports and registers very easily.
2. Single pins of the parallel ports can be easily addressed with going into the trouble of extracting them from bytes.
3. There are various statements to provide nibble or bit operations which are quite common in automation.

4. The name of the registers is also different.

(ii). Program Memory:

The program memory is stored on an on-chip flash EEPROM which can be erased and reprogrammed very easily and is highly stable to guarantee its continous use for many years in automation. In AT89C51 it is 4 kilo bytes, in AT89C52 it is 8K and so on.

(iii). Data Memory:

The RAM is bit lower only 128-256 bytes, but it is enough for most of the automation requirements. It is faster than conventional RAMs and external RAM of upto 1 Mega Byte can be easily added, but at the sacrifice of two parallel ports.

(iv). Registers:

Registers are fast dynamic memory usually contained in a microprocessor to provide faster access. Just like 8086 and newer microprocessors, Atmel chipe contain registers named:

A-Accumulator(ACC)
R0-8 bit General Purpose Register
R1-8 bit General Purpose Register
R2-8 bit General Purpose Register
R3-8 bit General Purpose Register
R4-8 bit General Purpose Register
R5-8 bit General Purpose Register
R6-8 bit General Purpose Register
R7-8 bit General Purpose Register
DPTR-16 bit Register
P0-8 bit Parallel Port
P1-8 bit Parallel Port
P2-8 bit Parallel Port
P3-8 bit Parallel Port
SP-8 bit Serial Port
T0-16 bit Timer
T1-16 bit Timer
and others.

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(v). Parallel Port:

There are four parallel ports namely P0, P1, P2 and P3 with registers, which can be used as input as well as output. Each bit can be individually addressed and set as both input or output and thus provides ease in programming. The parallel ports may be used to control robot manipulators, thermocouples, pressure transducers, motors, actuators, etc.

(vi). Serial Port:

There is one serial port provided in port 3 which can be used as serial port as well as parallel port. The two connections RxD and TxD allows the use of only two wires to communicate between two micro-controllers. There are different modes of serial port and at multiprocessor communication mode it can used to communicate between more than one micro-controllers using Client-Server Model, and each micro-controller can be addressed. The serial port is provided with an interrupt which is used to inform the processor about the arrival of data, this can also be disabled it data polling is required.

(vii). Interupt:

There are five to six interupts provide in the system which include two external interupts, one serial, and two to three timer counter interupts. An interupt is used to stop the processor function temporarily than perform a specific function like receiving serial.

(viii). Timer Counter:

Two to three timer counters are provided to enable micro-controller to count frequencies. These may be used in applications like frequency counting, baud rate determination for serial ports, etc.

3. Local Area Network:

Local Area Network is used to connect the different computers in various departments with a central server. A typical network consists of a Server usually running Windows NT or Windows 2000, Client Computers running Windows 95-2000 or Windows NT, Network Hub, Network Cards usually Ethernet card. The Client and Server Computers with Ethernet or LAN Card installed in ISA or PCI Slots are connected to Network Hub (central exchange or switcher) by unshielded twisted cable, usually of three pairs. Common protocols like TCP/IP, IPX/SPX and NetBIOU can be used to communicate between the computers. The remote users from any where in the World can be connected by telephone line on the server and can access the entire network.

4. PLC Network:

A PLC Network can be established in various sections of automation by simply connected RxD and TxD wires of each micro-controller. One micro-controller is usually assigned as Server or Host micro-controller and may be used to pass tockens to the client micro-controllers and act as a bridge between the network and the external computer. High Speed TTL Buffers may be used to amplify the signal in large networks and idealy 128 micro-controllers can be linked like this.

Pakistan Steel Mill Automation:

All the above devices can be integrated to fully automate Pakistan Steel Mill at Karachi. Although it is automated already and a LAN network already exists there, but it still require various operators and workers. What my target is to give some ideas about how to automate it fully and run it without operators at night time, which will result in the lower expenses as less staff is required and at the same time higher quality as everything is computer controlled and no human skill is effective on the final product.

1. Raw Materials Preparation Plant:

The plant is intended for receiving, storing and preparing raw materials for iron and steel making plants and Refractories Production. The materials to be stored and processed are:

Raw Material	**Job to be Done**	**Usage**
Iron Ore	Stored and Processed	Fe Source
Manganese Ore	Stored and Processed	Steel Additive
Lime Stone	Stored and Processed	Fuxing
Dolomite	Stored and Processed	Calcination
Tar-bonded Dolomite	Stored and Processed	Refractories
Bauxite and Fluorspar	Stored and Processed	Steel Additive
Refractory Clays	Stored and Processed	Refractories
Coke	Stored	Fuel

Other Additives Stored and Processed Steel Additives

The various sections of this department are:

(i). Reception and Storage Facility:

Reception and Storage Facility may be manual or automatic by using Automated Ground Vehicles, CCTV Cameras for record, Manipulators for loading and unloading. The raw material after unloading from the ships on the sea ports by robot manipulators may be put on already existing conveyor belts and transfered to the plant. Here the robot manipulators unload it from the conveyor belt and transfer them to the storage area in bins carried by Automated Ground Vehicles. On requirement the bins are carried to cruching plant and returned for temporary storage.

(ii). Crushing and Screening Plant:

Upon requirement the raw material is carried here for crushing by AGVs and unloaded from bins by robot manipulators. After crushing the crushed material is passed through screens and collected again in the bins which are carried to storage area or the sintering plant.

(iii). Sintering Plant:

Raw material and Coke fines (from coke and by-product plant) in the bins brought by AGVs is unloaded and entered in the sinter plant which is running under the control of a computer, manipulators, actuators and motors and is sensed by thermocouples, computerized screens, etc. After sintering, crushing and screening the sintered charge is collected in bins and sent to the iron making plant. Sinter samples are taken to labs for composition analysis.

2. Coke Oven and By-Product Plant:

The coke is carried from the storage area by AGV's in bins. After reaching here coke is unloaded from bins and put in coke oven. After oven it is dry quenched by the aid of robot manipulators with external parts of high temperature resistant material. The cold quenched coke is then blended with coal and collected in bins and transported to storage area for temporary storage by AGV's. The by-product plant can be automated on the similar basis. Time to time samples of coke and by-products are collected from munipulators and screens and transported to Labs for composition analysis.

3. Iron Making Plant:

The sintered charge and coke are brought in bins by AGVs and are unloaded in skips by manipulators and fed to the blast furnace.The Double bell loading system is already automated by actuators. The thermocouples installed in the ports and RTD (Resistance Themal Detectors) incapsulated in outer or middle layer of refractory bricks are connected with microcontroller via analog to digital converters, and in micro-controller program memory there are lookup tables to convert readings into absolute centigrade temperature which can be fed to the attached computer. The pressure sensors, gas flow meters and others connected in gas treatment section are also integrated to the computer by numerous micro-controllers. The hot-blast stoves are controlled by micro-controllers with digtal to analog converters and a temperature can be maintained from the computer. The pressure and temperature of the furnace and gas storage vessels is strinctly monitored by more than two computers to allow proper functioning.

The hot material from metal notch is poured into a ladle controlled by an already existing manipulator in the Hot-Metal Relining Shop. Slag is seperated by using existing techniques and some manual technique may be automated by interfacing circuits and devices as previously discussed. The hot metal ladle is then transfered to the steel making plant by mobile manipulators. Samples of pig iron are carried to lab by using existing automation techniques.

4. Steelmaking Plant:

The hot metal in the ladle is poured into large steel converters and oxygen gas is blown. Samples of oxygen are carried to labs by small pipes and pumps for composition analysis. The off-take gases from the top of the converter are analyzed for FeO and CO_2 by using a small on-floor gas mass spectroscope. Numerous RTDs are encpsulated in outer layer bricks of the converter to allow temperature measurement. After complete oxygen blowing the molten steel is poured into ladles which carry it to continous casting plant.

5. Steel Forming Plant:

This plant contains continous casting equipment which converts molten steel into continous long billets by rapid quenching with water. The temperature of the continous casting plant is sensed by thermocouples and the process is controlled by various manipulators. Samples of molten steel are take at specific intervals to transfer to labs for composition analysis.

The final billets are cold and hot rolled, cut and stored in product storage area temporarily and transported out of the Mill by human driven trucks and long vehicles. All the billet handling in the plant is done by very strong hydraulically driven robot manipulators.

Conclusion:

Well to put in a nut shell, the iron and steel making plant can be put on a complete automation with help from local engineers in quite less investment. According to my suggestion the process should be carried out gradually by automating one section at a time and after completion all the sections are automated by central computer. The proper automation depends upon the skills of the team of software developers. Both the hardware and software engineers should be atleast graduate or diploma holders in Metallurgy to fully understand the processes and automate them accordingly. Industrial Automation of Metallurgical Industries is a new field and is very prospective one. Indian Universities are giving a lot of emphasis on their metallurgists to take interests in computing and automation. Some of the Pakistan Industries are being automated by Indian Metallurgists.

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