Automation control system for different solutions of modern Roughing mill

Introduction
The increasing need of several steel producers to combine flexibility, rolling speed performances and high quality of finishing products is pushing mechanical and automation suppliers to find and develop solutions with a high technological impact, able to ensure quick answers to changing and dynamic market requirements.

Furthermore possible dimensional constraints of production site, both for green field projects and revamping ones, don’t allow sometimes to implement typical configuration of rolling mill for long products, due to the absence of enough spaces for installing a continuous roughing mill of horizontal & vertical stands.

In this paper we’ll present some four hands projects, developed by AIC’s technical department side by side with the most important mechanical suppliers to optimize different roughing mill groups and to minimize the rolling time, thanks to an innovative engineering approach and advanced strategies and methodologies of automation software packages. The experience and the results of these jobs demonstrate that innovative mill configuration allow to achieve a reduction of mechanical and erection costs as well as smaller footprint.

AIC is a global system integrator and supplier of Electrical and Automation systems for the whole Metals industry. In the next figure we show a traditional continuous roughing mill managed by AIC’s electrical and automation system.

Fig. 1-2 Traditional Continuous Roughing Mills of H+V stands and example of typical main control desk
Different solutions for state of the art roughers

In the last years AIC successfully implemented several project of roughing mill automation, each one designed and developed with different main mechanical suppliers, according to space requirement and constraint and to productive/quality needs of the final customer.

Some of the most significant examples of modern Roughers are as per follow:

- Enhanced 3Hi stand, to meet the target of capital cost savings and to manage big motors with easy starting process
- Blooming mill with fixed reversible stand
- Horizontal Sliding reversible stand
- Horizontal + Vertical reversing stand
- Horizontal + Vertical Sliding reversible stand

![Fig. 3-4 Main DC Drives Panel for Blooming Mill control with Nidec-Ansaldo and ABB DC Drive](image)

3Hi stand
The most classical design for single stand roughing mill is 3Hi, often equipped with a fixed speed motor.

Even though very old and usually completely manual, this design can nowadays be equipped with automated auxiliary devices that keeps it successful where cost effective applications are required.

For example electrically controlled manipulators, whose alignment is continuously guaranteed by PLC, can greatly help the operator achieve high and consistent throughput, especially if dedicated hi definition cameras are installed.
Blooming mill with fixed reversible stand
Automation & control system for a compact and very flexible blooming mill for special steel has been designed and installed in cooperation with Siemens VAI by AIC, based on enhanced one fixed reversible stand.

The solution described below is very interesting due to high configurable setting and the capability of rolling a large range of billet dimensions and to allow the production of wide range of final products as H, U or round profiles.

The configuration of mechanical group included:

- Furnace exit roller way, divided and managed into 5 sections
- Roughing mill exit roller way to existing intermediate mill, divided and managed into 4 sections
- Fixed reversible rougher suited with nr. 2 motors in electrical & mechanical axis for the control of main rolls and nr. 2 motors in electrical axis only for gap adjustment
- Upstream and downstream hydraulic alignment devices complete of fingers suited to properly turn the billets
- Upstream and downstream hydraulic tilting devices
- 4-section transfer carriages in electrical axis

The upstream and downstream roller way is now managed by existing motors (preserved with a significant economic saving), controlled by AC multidrive panel suited with IGBT DC Bus supply.

The speed control of the rolls of blooming mill is performed by two Siemens 1800kW AC motors (master & slave) with double winding, each controlled by nr. 4 Siemens Inverters in multidrive configuration (900kW each), with nr. 3 DC Bus suppliers with IGBT technology (1100kW each).

Roll gap adjustment.
The roll gap adjustment (opening and closing) is controlled by two AC motors in electrical axis; they can ensure great positioning results:

- ± 0,25mm during the positioning movement
- ±0,01 mm at the end of positioning phase

Before each rolling pass, the top roll position is adjusted using screw down, according to the bottom roll position and the required gap between the roll cylinders. For the lower roll screws, the homing function means that the screws move down till they are not moving anymore (mechanical stop), in this case this point is considered as the home position. The positioning feedback is read by nr. 2 incremental encoder aboard of AC motors and nr. 2 absolute encoder directly connected to the screws, in order to verify the right position.
Homing function means to read the actual encoder value and to store it in the PLC and consider it as offset.

Although the two screws are mechanically uncoupled, a careful alignment control must be ensured to avoid mechanical seizing of the screws. To ensure this, the automatic control system continuously performs an electrical axis control on the motors. To perform a proper roll gap adjustment both the screws start at gap speed $v_{gap}$, set on HMI, in order to reach the set point position; the axis are position controlled during all phases.

$$d_{DS} = d_{bottom} - \frac{\phi_{bottom}}{2} - \frac{\phi_{top}}{2} - d_{gap-DS} \; @v = v_{gap}$$

$$d_{OS} = d_{bottom} - \frac{\phi_{bottom}}{2} - \frac{\phi_{top}}{2} - d_{gap-OS} \; @v = v_{gap}$$

<table>
<thead>
<tr>
<th>$d_{DS}$ (mm)</th>
<th>Reference position for DS screw</th>
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<tbody>
<tr>
<td>$d_{OS}$ (mm)</td>
<td>Reference position for OS screw</td>
</tr>
<tr>
<td>$d_{bottom}$ (mm)</td>
<td>Bottom roll position</td>
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<tr>
<td>$\Phi_{bottom}$ (mm)</td>
<td>Bottom roll diameter</td>
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<tr>
<td>$\Phi_{top}$ (mm)</td>
<td>Top roll diameter</td>
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<tr>
<td>$d_{gap-DS}$ (mm)</td>
<td>Roll gap DS</td>
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<tr>
<td>$d_{gap-OS}$ (mm)</td>
<td>Roll gap OS</td>
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The set point position must always be reached coming from the top and the screw stops when the set point position is reached.

**Upstream and downstream Alignment & Tilting Devices.**

In order to ensure an optimal travel in and thread in of the bloom against the reversible stand (at the speed scheduled into the PLC program) the entry and exit manipulator automatically aligns the material in front of the correct groove according to the schedule; the manipulators are singly controlled through hydraulic motors with a positioning feedback by absolute encoders.

They can reach an alignment speed about 400 mm/s with a precision of ±1 mm and a pressure on the bloom of 170 bar. The manipulators are also equipped with fingers that are used to make material tilting, depending on the rolling needs. Each positioning task is controlled by a proportional valve and a position value read into the PLC.
Rolling cycle into the roughing mill.
The bloom or the billet from the reheating furnace, after a descaling process, is discharged on a new entry roller way and transferred into the upstream alignment devices at a speed about 3 m/s; in this position the billet is stopped, pressed, measured (width measuring) and it can be also tilted, depending on the rolling recipe. The material then gets guided to the center of the working groove (set by rolling recipe) and it can be finally inserted and rolled after receiving all consents of right positioning of the machine (rolls gap, upstream and downstream alignment and tilting devices).

Each rolling pass is based on 3 main phases:
- Bloom charging
- Bloom threading and unthreading
- Bloom discharging

In these phases the rolling speed can change according to the recipe parameters (usually a low speed during charging and discharging and a high speed during rolling).

The automation system controls the alignment devices settings:
- In the bloom charging phase they have to be maintained larger than the billet, in order to allow it to go forward
- In the bloom threading and unthreading they can be used to press the bloom (upstream or downstream), in order to allow a better alignment into the groove and to avoid the overturn of the billet.
- In the bloom discharging phase the billet must be stopped in the manipulators in order to allow a 90° rotation (if required), straightened, measured and then translated to start with a subsequent rolling pass.

The AIC automation system is designed and developed to allow from 1 to 11 rolling passes, with different settings according to easy and user-friendly recipes (summarized in only one HMI screen); it allows to reach up to 225 different set-up for each pass, for a total number of 2475 possible set-up for each billet.

Fig.8 HMI Screen showing roughing mill synoptic

Results and Targets achieved
After this revamping project, the roughing process is now completely controlled by automation program, without any need of manually setting of the operators; the machine can operate by a remote control from main command desk (positioned more than 40 meters away) thanks to special cameras equipped with infrared filters, allowing to check both the positions of the machines and the billets, avoiding problems related to reverberations of very high temperatures.

This reversible blooming mill ensure a significant improvement of the flexibility of the plant, because it requires only about 30 minutes for changing the rolls of the stand and it allows a quickly shift to a different rolling campaign for another production range (just through a different recipe set on HMI).

Another great result is an excellent repeatability and profile accuracy of the resulting bar that is going to be loaded into the downstream finishing rolling mill.
Roughing mill with horizontal sliding reversible stand

A different solution for a compact and very flexible roughing mill for special steel was designed and in an Italian plant for special steel production, based on horizontal sliding reversible stand.

As per mechanical layout below, this roughing mill solution is based on an horizontal sliding stand, controlled by two 900 kW Ansaldo DC Motors (600V); these motors are in mechanical & electrical axis and are connected to the machine by spindles; they are driven by two main DC Drives Panels with a power current of 2500A each.

During the starting and reversing phases, acceleration and deceleration ramp of the DC drives is about 3s (usually with a total current limit of 5000 A), allowing very quick speed reversing.

The roughing mill can be set up to 8 passes with a constant roll gap and, due to the horizontal sliding movement, with a fixed rolling line; the stand shifting is implemented through a proportional servo valve in order to ensure the right positioning to the next selected working groove without having to modify the rolling line.

This easy but efficient process can be made with the same flexibility for each single pass; the easy turning and shifting tasks require no further movement of the billet into the working groove, so the rolling cycle can be completely automatic, without requirement of any operator activity. To ensure an efficient control of rolling direction upstream and downstream alignment devices are also installed: they are digitally controlled with a setting feedback through solenoid valves.

On one side of the sliding stand a tilting device is installed, managed by a proportional servo valve and by a positioning feedback through an absolute SSI encoder; moreover a positioning feedback of the stand as well as alignment devices is implemented through a linear transducer (Temposonic type).
Results and Targets achieved

The revamping job was planned and designed side by side by the mechanical & electrical suppliers to meet the customer need of updating the existing 3Hi roughing group with a state of the art sliding and reversing solution. The ultimate aim of the update was to reduce the number of stands changes of the downstream intermediate continuous mill.

AIC scope of supply in this project included complete turn key electrical equipment:
- MV Switchgear for continuous mill
- MV/LV Transformers
- DC motors for roughing mill
- Power control & PLC panels for roughing and continuous mill, complete of new DC Drive Panels for new 8 stands
- PLC SW and HMI in client/server configuration
- PLC Safety system

Thanks to this new roughing mill and a new complete automation system the customer can now reach an efficient production rate, even higher than the initial target of the investment (rolled t/h).

The project’s performances were achieved in just one and a half days after the start-up of new control system with billets of 6 meters length.
**Horizontal + vertical fixed reversible stands breakdown mill**

A different approach to compact roughing mill design that avoids installation of bar turner and movable alignment devices is the horizontal + vertical reversible stands group. This solution can be designed in two different variants: with fixed stands and with sliding stands.

AIC developed a fixed stands solution for a customer’s plant where a wide range of special steel is produced: heat treated profiles, plates, angles with a range of about 1500 different products/year and a theoretical plant productivity of 200 kt/y.

In this project stands are equipped with automatic gap adjustment and automatically adjustable entry / exit guides. One of the main differences, from the process automation point of view, between single stand and double stand solution, is that in the latter case each pass must be treated as a cascade of two stands, and process parameters must be controlled accordingly.

AIC solution for rolling mill process automation, RACS (Roll mill Automation Control System) was designed from the very beginning to be very flexible, and can be successfully implemented also for this very specific application. RACS enables the automation to control all rolling parameters, like:

- stand speed
- load-in signals
- load-in overspeed
- tension control
- min/max and mean rolling torque

All rolling parameters are controlled exactly the same way as for multi-stand continuous rolling mills, and the same happens for the operator desk interface and parameters. This uniformity of operator interface provides a very easy learning process for operators that already work on an intermediate/finishing continuous mill controlled by the same RACS system. Tight integration between RACS standard system and the specific application auxiliary devices (gap adjustments, entry/exit guides etc.) is crucial to leverage the best of both systems and achieve best performance level by optimizing all movements.

Fig.13-14 H+V fixed reversible stands and Drives panel
Roughing mill with housingless horizontal + vertical sliding reversible stands

An advanced solution for a state of the art roughing mill for special steel has been designed and installed in Metallurgica Marcora, Cuggiono plant (Milan – Italy), based on horizontal + vertical sliding reversible stand. A similar solution allows to reach significant benefits, with a very compact layout and without the need of manipulators / tilting devices to turn the billet (needed in solution with just a single reversible stand).

The electrical scope of supply included:
- Nr. 2 923kW Ansaldo DC Motors
- Main DC drives panels suited to drive new stands
- PLC & HMI system

Fig. 13-14-15 H+V Reversible Sliding Stand and related control desk
Set-up and automation cycle
The two sliding stands are managed through an hydraulic positioning control, with positioning feedback by absolute encoders. Similarly to the fixed H+V reversing stands, AIC rolling mill control standard solution (RACS) is used to control rolling speed adjustments of the stands. A very tight integration between RACS system and stand positioning automation (all done by AIC) is the base to achieve high throughput by doing as many movements as possible in parallel. An HMI system was also included in the project, as shown in image nr. 15.

The production cycle is now completely automated from the reheating furnace discharging:
- Roller way automation of reheating furnace exit
- Chain transfer for threading (first pass)
- Rolling phase depending on the charged recipe
- Continuity control and related alarm on HMI signalling lacking threading
- Optimization for an anticipated positioning of the machines

Optimization of each solution as a key target
The described compact and technological solutions for modern roughing mills allow steel producers to obtain several benefits from a technical and economical point of view. Besides a capital investment saving, thanks to a reduction of stand costs and related electrical and erection costs, the customer can rely on a highly flexible system, able to ensure high production quality.

From the electrical & automation point of view, the H+V breakdown mills, while consisting in only two sliding or fixed stands, can be configured and managed like a traditional rolling mill, taking great advantage of know-how and settings. As a matter of fact the operator can control the rolling process through the AIC’s RACS system, especially developed for long product rolling mills, and its several different kinds of task-specific regulators, each one with a dedicated set of parameters. For example, in order to achieve the maximum quality of the rolled material, the rolling process shall minimize the stresses on the material and shall thus monitor and adjust the rolling tension on the material during the process (tension control) in the roughing area.

RACS has been successfully implemented for quantity-focused systems (for example construction steel mills) and quality-focused systems (for example profile and special steel / super alloy mills); it is designed to let the user focus on very few, necessary parameters, while the other ones are set during commissioning and then recorded in recipes, freeing the user from the necessity to continuously check and adjust internal parameters.

To meet the quality and efficiency customer’s needs each shown solution is highly customized and optimized, in order to always ensure the best set up and performances.

Authors
Mr. Marco Capitanio / Mr. Roberto Migliorati / Mr. Arondi Stefano
Automazioni Industriali Capitanio
Via del bosco, 10
25076 Odolo (Brescia) – Italy