PRODUCTION OPTIMIZATION BY APPLYING ADVANCED PLANNING SYSTEMS (APS) FOR METALS INDUSTRY[1]

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Abstract

The utilization of production facilities in an optimum way, with reliable due date fulfillment, reducing raw material and energy consumption, in a continuous high quality production, are challenges that iron and steel company are facing in their business every day. By applying APS, such goals can be achieved to increase the competiveness of iron and steel producers. A sophisticated APS provides fast decisions to match the company specific KPIs (Key-Performance-Indicators) considering complex rules like product and order mix, production routings, processing and transport times, availability of important production resources, specific technological, steel grade and energy related constraints etc. The APS solution presented in this work - following the latest Industry standards in ISA 95 - is used to optimize single processes or even complex integrated plants from iron & steel making via hot to cold rolling and processing. This article describes APS systems in general and a case covering the processes from Blast Furnace to Slab Casting.

Keywords: APS; ISA 95; Planning; Scheduling.

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1 INTRODUCTION

Planning and scheduling systems, as depicted in the following figure extracted from the ISA95,[(1)] play roles in levels 3 and 4.

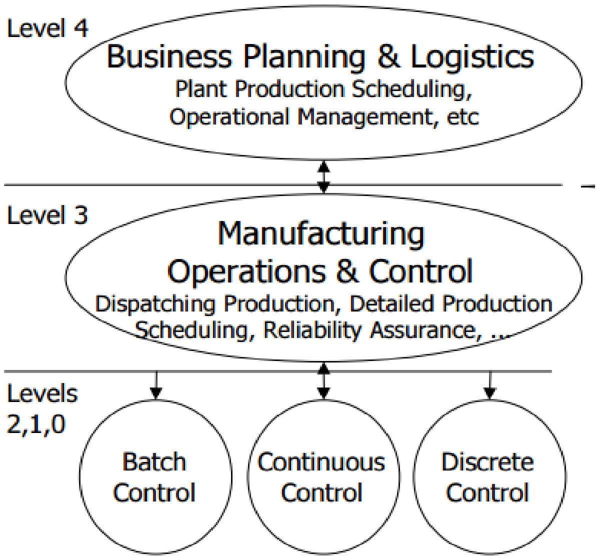


Figure 1 – Functional hierarchy.[(1)]

Whole plants Production Scheduling systems are in Level 4. Those systems are closer to IT or Supply Chain kind of departments in most enterprises. Main problems to be solved in that level are Capacity and Availability. As it is defined in ISA95:[(1)]

> Extract 1 – Level 4 Activities according to ISA 95
> “5.1.1 Level 4 activities
> j) Determining the optimum inventory levels of raw materials, energy sources, spare parts, and goods in process at each storage point. These functions also include materials requirements planning (MRP) and spare parts procurement.
> k) Modifying the basic plant production schedule as necessary whenever major production interruptions occur.
> l) Capacity planning, based on all of the above activities.”

In this work we analyze Detailed Schedulers, in the scope of Level 3 MES, “3.0 Production Control”.

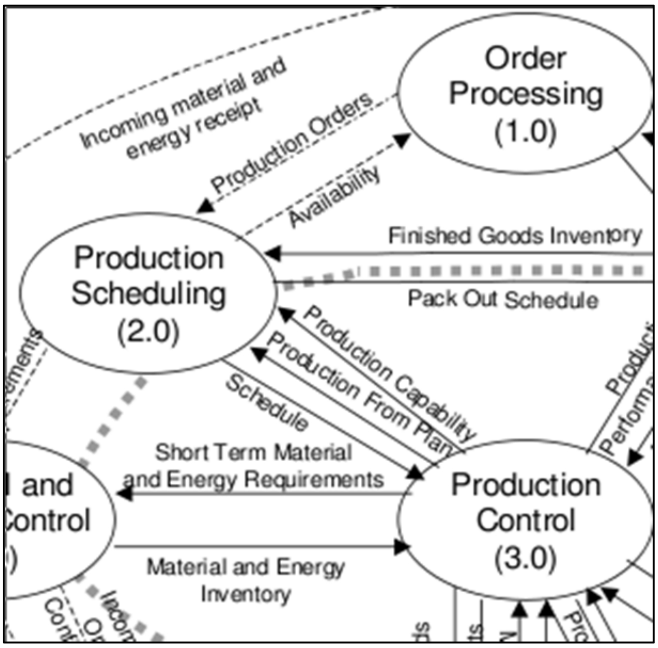


Figure 2 – Extract from Functional enterprise-control model.[1]

Extract 2 – Level 3 Activities related to APS[1]

"5.1.2.8 Operations and detailed scheduling
The control domain includes the functionality of providing sequencing based on priorities, attributes, characteristics, and production rules associated with specific production equipment and specific product characteristics, such as shape, color sequencing or other characteristics that, when scheduled in sequence properly, minimize setup. Operations and detailed scheduling is finite and it recognizes alternative and overlapping/parallel operations in order to calculate in detail the exact time of equipment loading and adjustment to shift patterns."

1.1 Scope of the Referenced Project

The APS system for the referenced project was named "Siemens APS Iron/Steel". The detail scheduling functions covered in the referenced project starts from the input of the Caster planning, in terms of sequences of Heats that should be made at the relative timing proposed. The Caster planning is not integrated, so when serious misalignment from planning and executing appears, a new caster schedule is necessary. The caster planning usually belongs to supply chain departments while the detail scheduling for the steel making is closer to operations on the shop floor.
Another input to the APS Iron/Steel system is the production rate of the Blast Furnaces (BF), which is the supply of Iron to make the necessary Steel to supply the Casters. Rates for the BF are defined in higher (Level 4) systems, and cannot be determined by the DS. According to the process technology, it is not possible to control and fine tune the BF rate. It is expected that BF rates are enough to produce the Caster sequences delivered by supply chain. In order to cover possible problems, the BF rates use to be greater than the steel demand in the casters.
With iron information, and the plant shop floor information, the system creates a detailed scheduling (which task to do in which equipment in which exact timing) optimizing the utilization of material and equipment.

The detailed scheduling for the steel and iron making areas, which is the main goal of this system, it is required for this project in a continuously moving window for 48 hours.
The Materials taken into consideration are the Iron from BF and Steel made in Basic Oxygen Furnaces (BOF). The system can consider energy or oxygen need if it is specified in the corresponding description of the products (in ISA95 terms, the Product Segments). The Equipment taken into consideration is the BF, other Iron making facilities (for disposal of exceeding iron), the steel making equipment, and the transport systems (cranes, ladle transfer cars).

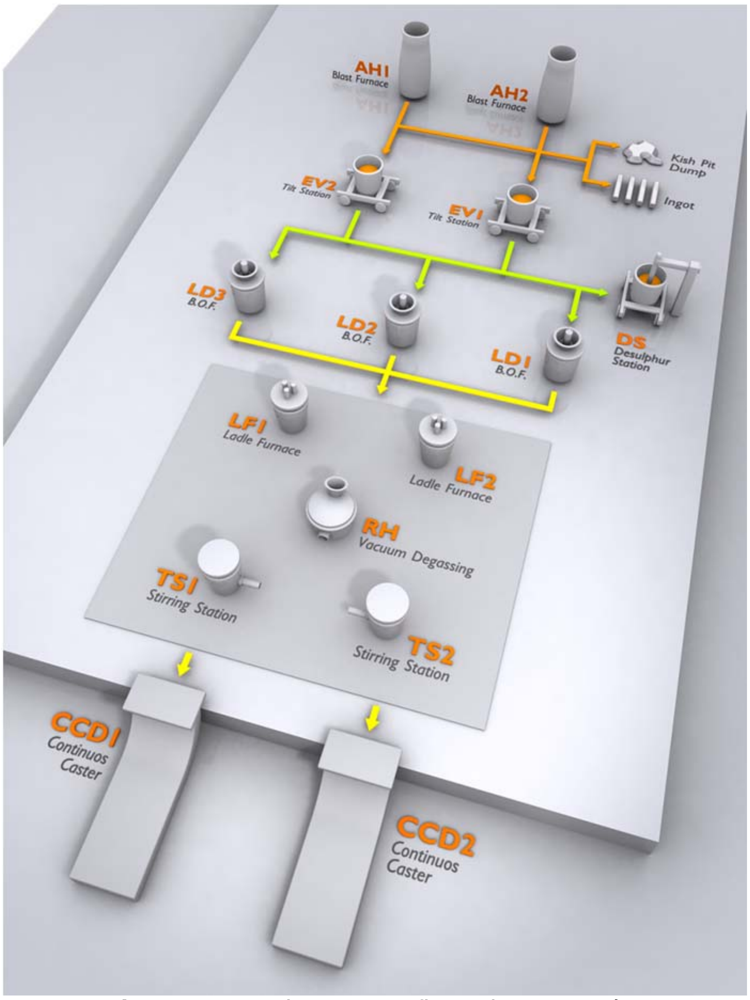


Figure 3 – Equipment configuration example.

Given the description of the Advanced Planning and Scheduling (APS) systems in general, and the referenced project in particular, it follows that detailed scheduling in the steel making industry is, in general, a NP problem. Optimization, and hence, algorithms for solving the problem in a general way are not established. There is a plethora of ideas, algorithms and systems.[(2)]
For all the available options, the conclusion was, for APS Iron/Steel and the reference project, that a flexible approach should be used, to cover all the functionalities required, including not only pure planning functions and the necessary optimization, but also the necessary synchronization according to shop floor signals regarding the actual production status.

2 MATERIAL AND METHODS

It was chosen a dedicated APS systems development environment. On top of it, a comprehensive framework adjusted to ISA95 was made. This development environment gives several infrastructure facilities for APS specifics, as Gantt charts and integration technologies. The development environment and the final system interprets a high level language with visual design tools for the GUI, transparent persistency, and some other advantages, more suitable to express the object model of ISA95 and the algorithms needed to solve the scheduling problem.

Another function of the system is the capacity of maintain several scenarios. Each scenario can have different planning choices, and then KPIs could be compared. Each one has a separate and parallel computation for shop floor signals.

The integration technologies abovementioned are, Relational Data Bases for massive low frequency interchange (mostly, master data from another levels), and SOAP messages, following ISA95 standard, for more frequent data (mostly, level2, shop floor information). The SOAP implementation is transactional and messages are queued. This gives as the known advantages of SOA architecture.

ISA95 is used not only to specify the schedule according to the *Production Schedule* object model, but also to process the feedback from the plant as *Production Performance* objects. The *Product Production Rules* (PPR) in general, and the chance to have more than one PPR (or path), for each steel grade, in particular, was of special importance. The flexibility of the object model expressed in terms of *Properties* and *Parameters* (opposed to a comprehensive list of fixed attributes) was exploited in several stages of the project, giving advantages to the final user too.

Algorithms used are local search type heuristics, based on the knowledge of the specifics on each topic, including choosing the best path (PPR), the best equipment, the best supply of iron for each demand, when to dump exceeding material, and so on. Next sections will show the specifics according to each function of the system.

3 THE SIEMENS APS IRON/STEEL SYSTEM

Figure 4 – General view of the APS Iron/Steel

3.1 The Caster Planning

Caster planning data is an input to APS Iron/Steel. It is, mostly, a sequence of Heats that should be delivered in a particular sequence and timing by the Steel Making area. The Caster planning is made in an external system, taken into account the demand of solid products (slabs, billets, blooms) for downstream processes. Each Heat data also contains the specific steel grade to be made.
Main goal for the planning of Continuous Caster facilities is to keep sequences as long as possible (given several technological constraints), diminishing the need of speed losses (strands setup, mold changes) between sequences.
It is usually possible that the responsible personnel for Caster planning are not present all the times in the plant, and that Casting and Steel making systems are decupled. This situation leads to the need of some freedom to change a delivered schedule for the Casters within the Steel Making Area realm, in a window of only some minutes, when some failure appears. This freedom is supplied at some extent by let the Steel making personnel to change *Tundish* sequences.
Once the Casting Planning is done, the Steel Making Planning can be done subject to the timing given by the casting.

3.2 Steel Making Planning

For each Heat in the caster planning, the information regarding the steps needed to make the steel grade required is analyzed. In terms of ISA95, this is the *Product Production Rule*, or PPR (shortly, path of equipments within the plant). Once those steps are determined, they should be placed in the planning in a way that no Equipment is executing 2 tasks at the same time, and, for any 2 consecutives steps for the same Heat, the previous should end before the next starts.

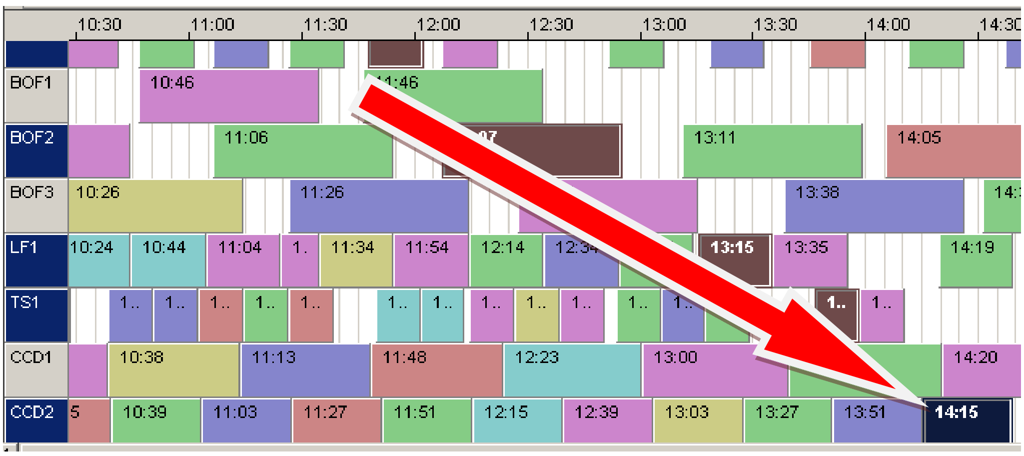


Figure 5 – Steeps for a Heat production in the schedule.

The strategy is to complete this planning from the last Heat to the first, and from the caster (last) task to the first in the PPR (usually, the connection to the Iron supply task).
Each steel grade could have more than one choice. This is not only regarding which specific Equipment will make the actual process segment, among all the available ones belonging to the same Equipment Class. Also, it is possible that a Steel grade could be realized following different sets of Equipment (different PPRs). At this point, the APS Iron/Steel will evaluate all possible PPRs, according to the current status of

the planning. It will choose the minimum lead time for each heat. Please note that, even if some PPR can be better in terms of duration when considered isolated, when this PPR is materialized in real Equipment, could be a bad choice due to occupancy or unavailability of those Equipments for this particular timing. So, what can be taken as a bad choice isolated, could be the best choice in a particular context. (This is a general mistake in planning, trying to take advantages of local minima instead of global scoring of a solution. But here the challenge is, also, to use current real time information from the shop floor).
Another job for the detail scheduler is to include PPRs for routine tasks not linked to a particular Heat, but related to the Equipment and how many Heats were made. Those tasks could be to replace some material or part of equipment, or more general cleaning activities. In APS Iron/Steel these tasks are fully configurable and a maximum and minimum frequency could be input, so the system can choose the best available place were to plan each task for the operators in the shop floor.
Steel making planning and scheduling ends when the first operation of each Heat is planned, which is the iron demand, that must be connected with the iron supply from the Blast Furnaces.

3.3 Iron Supply/Demand

The APS system is able to make a scheduling based on the iron supply for Blast Furnaces loading a Mixer and then to charging ladles for the Basic Oxygen Furnaces (BOF), or by in an Electric Arc Furnace (EAF) kind of facilities. It depends on the PPRs configured in the system. Connection between Iron supply form BFs and iron demand to load the charging ladles for the BOFs, is made by torpedo cars and Tilting Stations in the referenced project.
A simulation for the iron supply based on production rate is always present, having this way a simulated scheduling for the torpedo cars. Actual information from the plant will adjust the simulation to more realistic information for short term scheduling (within few hours), while the simulation helps in the long run (48 hours in the referenced project). The system presents Iron supply/demand as stock for instantaneous information, and also as supply and demand **rate**.
When Iron demand is known after the Steel making area planning, and all information regarding Iron supply is computed, the system finds the best assignation from torpedoes to charging ladles for the BOFs (these includes possible desulphur processes).

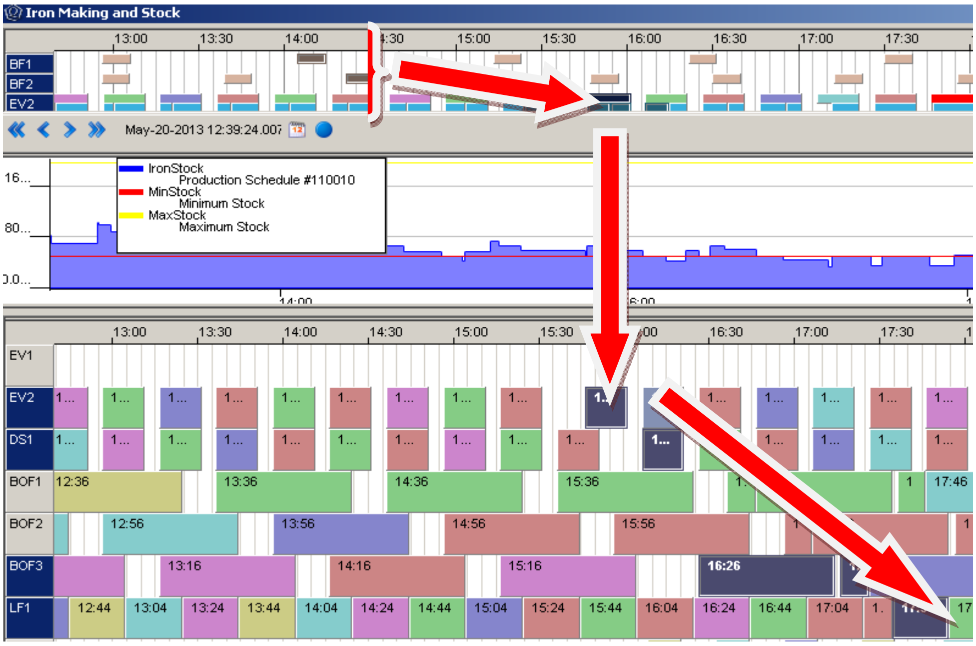


Figure 6 – Assignation from BF Supply to Steel Making demand.

Not assigned torpedoes (in general, not used Iron supply) are eligible for disposal according to the available resources (ingot making, dump yards, and so on) and optimization goals, mostly configured in corresponding PPRs in the master data.
When all "static" planning is done, still the system needs to consider the messages from the shop floor that indicates the actual occupancy and results from the continuously delivered scheduling against the flow of actual production signals.

3.4 Feedback from the Plant and the Frozen Zone

The messages received from the shop floor (ideally, from level 3 systems) are recorded as *Segments Responses* from the *Production Performance* according to the ISA95 object model. Those are connected to the planned *Segment Requirements* from the *Production Schedule*. In short, the planned and actual information is connected, and used to the system to adjust the schedule.
Considering the current time, there is a zone in the schedule defined for the Segments Requirements (the planned tasks) that has already been executed, and hence, has the corresponding Segment Response. Those tasks cannot be moved, and then, creates a frozen zone for scheduling proposes. All these occur in the past, but in case they are executed too late, a delay in the downstream pending tasks in the future is created. In order to recompute the scheduling, the system needs to make room for these tasks in the future. If there is another assignation of tasks to resources that can solve the delay, the system will use it. Anyway, there are cases in which the last task, which is the Caster segment, must be moved to the future.
To make it clear, please consider the following scenario. In the charts, the blue line is the current time, while segments with a grey line in the middle of the box are already confirmed by the shop floor as executed (most of them, on time).
Consider what happens if, in the first chart, the task starting 21:32 in BOF3 is executed too late, in a way that the next task (originally starting 22:33) is delayed. There is no room in BOF3 to move the tasks. Also, cannot be moved to BOF2 as the task starting at 21:53 has their predecessor tasks already confirmed, and hence, cannot be moved to the past. Please note that it seems to be room in BOF1. Finally, the system makes several shifts until a solution is found.

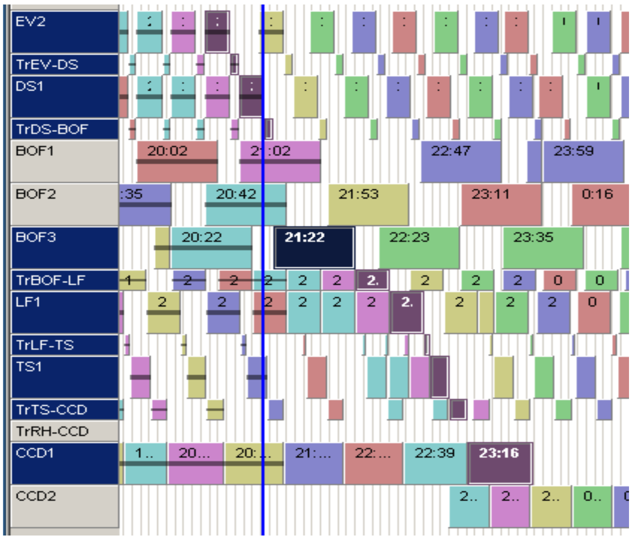


Figure 7 – Solving shop floor feedback problems: scenario.

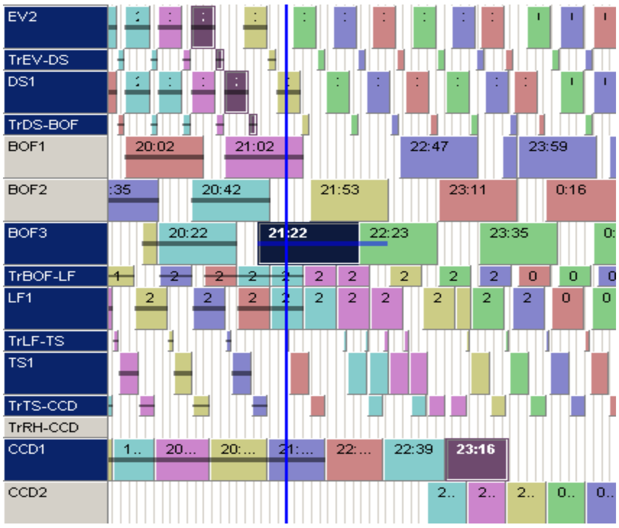


Figure 8 – Solving shop floor feedback problems: task actual duration is bigger.

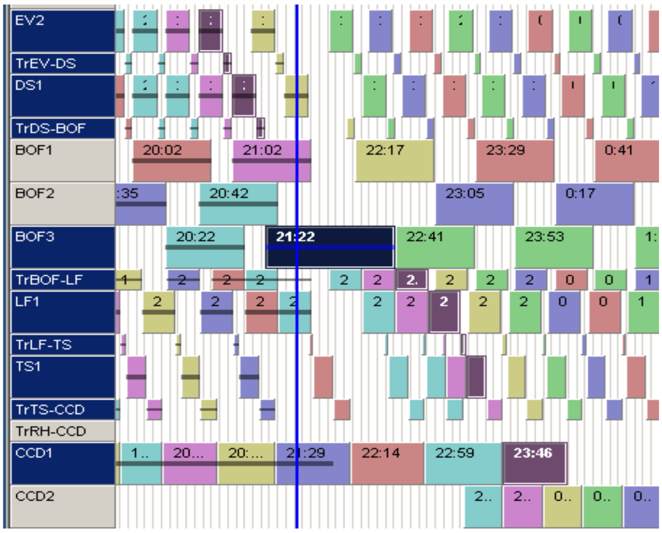
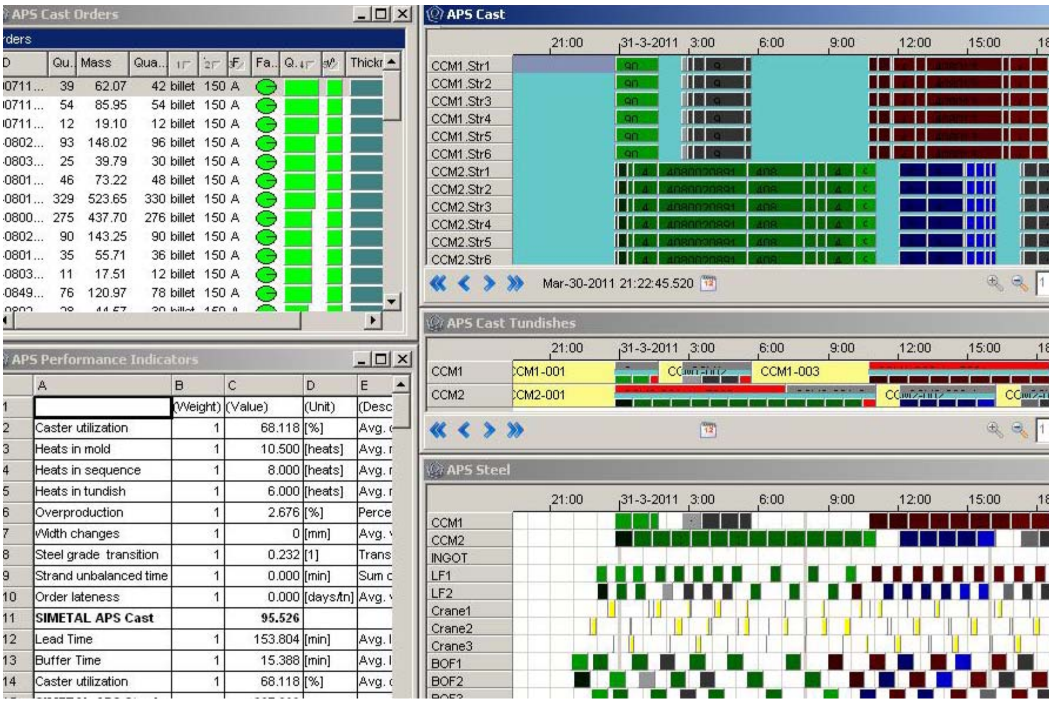


Figure 9 – Solving shop floor feedback problems: solution found.

Also, due to the very nature of the Continuous Casting equipment, the tasks (the Heat pouring) must be continuous. What happens if there is no room to relocate the tasks? Once choice is to break the heat sequence, creating a setup (a speed loss that must be avoided). The other choice is to decrease the speed of the Continuous Caster up to the limit possible for the product being casted. The system will choose the best according to the context. Shortage of Iron Supply could also lead to Caster reduced speed as well as a heat sequence break and a corresponding setup created. Having the Steel Making, Iron supply/demand assignation, and feedback received, the plan can be automatically delivered and executed, in a continuous iterative collaboration between the APS and the shop floor.

4 FUTURE WORKS

The Steel Shop scheduling and the Casting planning are usually decoupled. This can lead to problems when the detailed scheduling is altered isolated from the big picture of the planning. Also, considering current trends in Mini Mills and hot charging for downstream processes, it can be assumed that a more integrated planning and detail scheduling systems will be demanded for the Metals industry in the near future.
The following picture shows an integrated Casting/Steel making APS system, in which any change in the assignation of casting orders (slabs/blooms/billets) can be propagated up to the BOF and the effects shown in the same screen, along with integrated KPIs.



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