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REAL-TIME PRODUCTION PLANNING SYSTEMS SUPPORT INDUSTRY 4.0 REQUIREMENTS OF A SMART FACTORY*

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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, are challenges iron and steel companies are facing in their business every day. By using an APS system such goals can be achieved to increase the competiveness of iron and steel producers. A sophisticated APS supports the overall planning process by applying complex rules based on product and order mix, its production routings with corresponding processing and transport times and resource availability. Specific technological as well as steel grade and energy related constraints are also considered to meet company specific KPIs. A core feature of APS solution is to react online on deviations to plan during the production process. Deviations such as non-conformance of intermediate material attached to an order, sudden production delays, unavailability of important production resources, makes it necessary to update the production plan. In general the task of APS is to support the preferred work-to-order concept, by assigning work-orders to available production facilities along the product specific process route and generate optimized material sequences for critical work centers.
Keywords: APS; Industry 4.0; Scheduling; Planning.

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1 INTRODUCTION

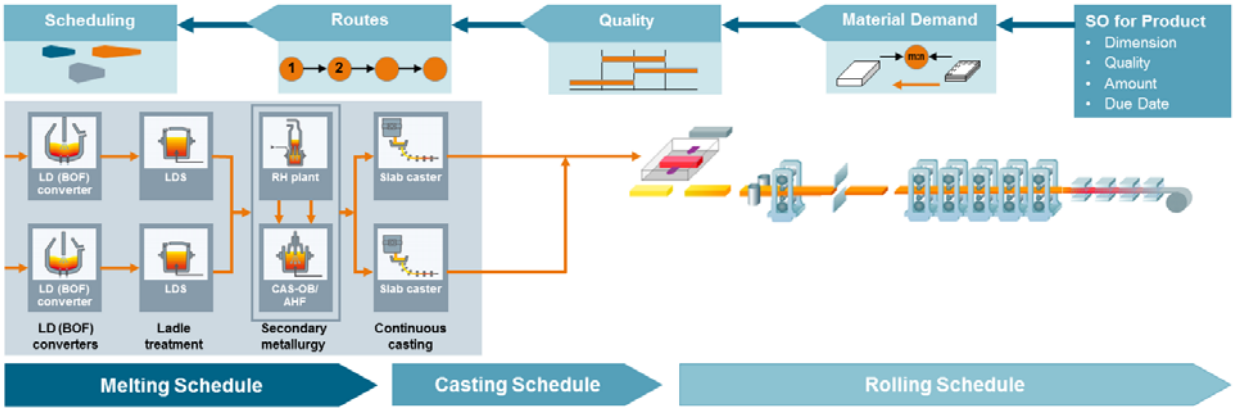

Figure 1 – Planning principle in a typical steel plant with downstream rolling mil

In general a customer order describes the product type, for example a galvanized coil, the steel grade, specific product requirements, like dimension, tensile strength etc., the amount and due date.

At the beginning of the planning process the production orders have to generated out of the customer orders, means in addition to “What” has to be produced, also “How” the production has to be organized, in order to deliver the required product in time.

For each final product the material demand has to be determined, e.g. for a galvanized coil, which hot band dimension has to be foreseen to produce the cold band in the cold rolling mill.

Also in other processes, like casting, complex material transformations have to be considered, to produce out of a large amount of liquid steel a number of solid steel blocks.

In order to evaluate and secure the product quality the APS plans all quality tests according to specific standards along the production route. Such sampling could be based on order specific requirements, that e.g. from every 5th product of an order a sample has to be taken at specific material locations. Also process related requirements must be considered, that e.g. at caster sequence start from every strand head a test piece has to be evaluated.

For complex processes like in iron and steel industry, an important issue to consider during generation of production orders are the different variations of the production routes in order to manufacture a product with the required properties. The selection between similar production processes, e.g. availability of several rolling mills where same products can be produced, is done according to capacity and sequencing in later planning phases.

An important step after releasing of the production orders for planning is the assignment of orders to free production capacities. The task of capacity planning is not to determine the exact time point and sequence of each material piece, but to roughly plan the order book. APS must be able, to place the orders along the time line in that way that the work centers are loaded in an optimal way, but not overloaded. In most cases after this capacity planning for each order a feedback to ERP is necessary.

The last step of a typical planning process is to do a detailed planning to generate an optimized sequence which shows for each material piece at which time and at which position in the production sequence it is treated at the different work centers.

2 MATERIAL AND METHODS

2.1 Product based APS Solution

The APS solution is based on a standard product with a HMI to show schedules in a graphical view, supporting drag & drop feature to enable manual adaptation of schedules. Based on the specific scheduling use case certain mathematical methods are applied, like genetic algorithms, to create schedules with a near optimum result with a reasonable calculation performance.

3 RESULTS AND DISCUSSION

3.1 APS use case for ESP

Arvedi ESP is a new generation of casting/rolling plants that allows the production of a wide range of high-quality and ultra-thin steel products in an endless casting-rolling process.

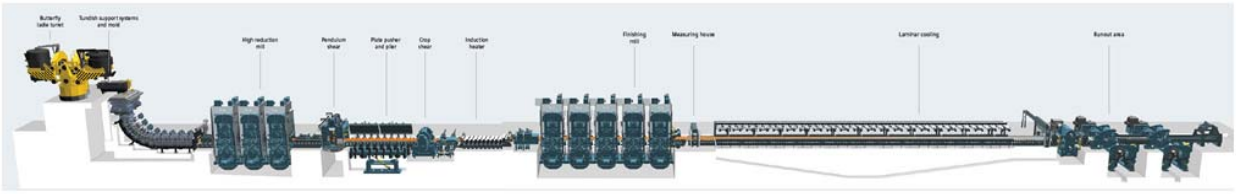

Figure 2 – Typical ESP Plant Layout

Due to the integrated nature of the production process traditional campaign planning approaches fall short of scheduling functions for ESP plants. The ESP detailed scheduling system combines the features of continuous caster and hot strip mill planning under consideration of technological ESP requirements.
ESP scheduling's task is to plan optimized sequences or campaigns of heats and ESP products, whereas a sequence is defined as a continuous ESP production run in between two casting campaigns. The created ESP heat sequence then serve as an input for heat coordination of the upstream steel plant.

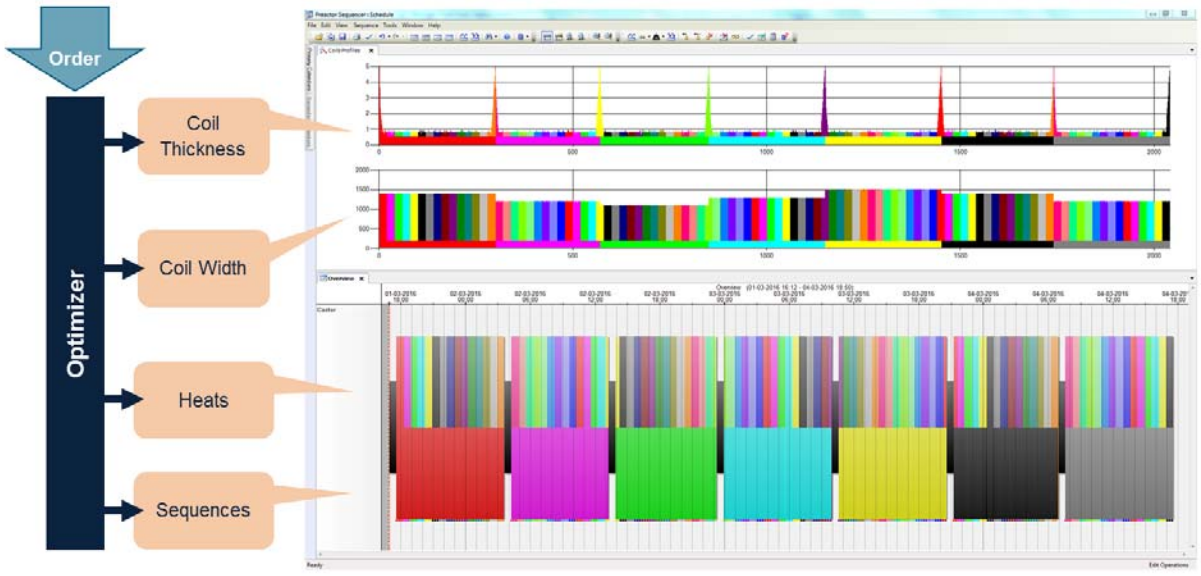

Figure 3 - typical ESP sequences

Above figure shows a scenario where based on the released order pool the minimum amount of sequences are scheduled. Each sequence consists of a number of heats considering allowed heat transitions. The coil orders are distributed over the campaign in an optimum manner, minimizing the number of thickness, width jumps and steel grade transitions. Major coil-to-coil constraints, like maximum allowed thickness & width jumps and other properties required for an effective sequence run are considered to achieve the overall goal of a high plant utilization without constraint violation.
In most cases already such a standard scenario is too complex to be scheduled manually in an efficient way, especially when a wide range of products linked to many small orders have to be produced. It requires a sophisticated automatic scheduling tool with tailored optimization algorithms, like the APS to build an efficient plan.

3.1.1 Industry 4.0, Smart Factory

Modern factories have to be capable to react to changes quickly and the planning system has to support it. Real-Time Rescheduling is an essential part of the APS solution to ensure the continuity of the endless casting and rolling process in case of "last-minute" changes.
Typical situations requiring Real-Time Rescheduling are:

- Last minute orders arrive or priority/due dates of orders change. In such a case either suitable products are found in the product yard and re-assigned to urgent orders and/or the planned but not yet produced objects of the current schedule are re-planned to consider the order changes.
- The actual heat weight reported just ahead of casting differs from the planned weight. The schedule of the affected heat is instantly updated, by changing coil weights within allowed limits or deleting /adding products to the planned heat.
- The chemical analysis of a heat at the caster shows a mismatch with the required steel grade of the original plan. Immediately the APS has to assign different orders to the heat matching the actual chemical composition.
- Machine or process problems within a sequence may require operations to deviate from the rolling plan. Targeted coil dimensions may not be achievable any more. The APS considers the new constraints and performs a re-planning for the remaining sequence assigning orders, which can still be produced.

The quick reaction of the whole ESP facility to a sudden change is only possible because of the tight coupling between the planning system and the ESP's process automation systems, which also support such sudden changes to the plan. Only the tight link between the systems involved allows the factory to become smart in the sense of Industry 4.0.

3.2 APS use Case for Mini Mills

A typical mini mill consists of one or more long rolling mills and its upstream steel making and casting facility to supply the required billets.
The difference to an ESP plant is that typically a billet yard exists between the melt/cast production step and the final rolling production side. Dealing with inventory adds another requirement to the APS and affects the planning process.
The task of the APS is to build rolling mill campaigns, which in turn are sequences of billets out of final long rolled product orders. An important input to generate a rolling

campaign is the actual inventory of the billet yard. Unplanned or unassigned billets from the yard are used, hence reserved, first when planning a rolling mill campaign. The missing material to fill up the campaign is then ordered from the steel making plant/caster. This material demand based on the created rolling sequences combined with heat-packing allows the upstream processes like caster and steel making to be scheduled as well, establishing a “pulling” process across the different work centers. By applying this integrated planning process from the scrap yard through to the rolling mill, The APS solution minimizes inventory while enabling customers to provide reliable due date promises: ATP – Available-To-Promise by considering the actual stock and CTP – Capable-To-Promise by considering future upstream production of billets or blooms.

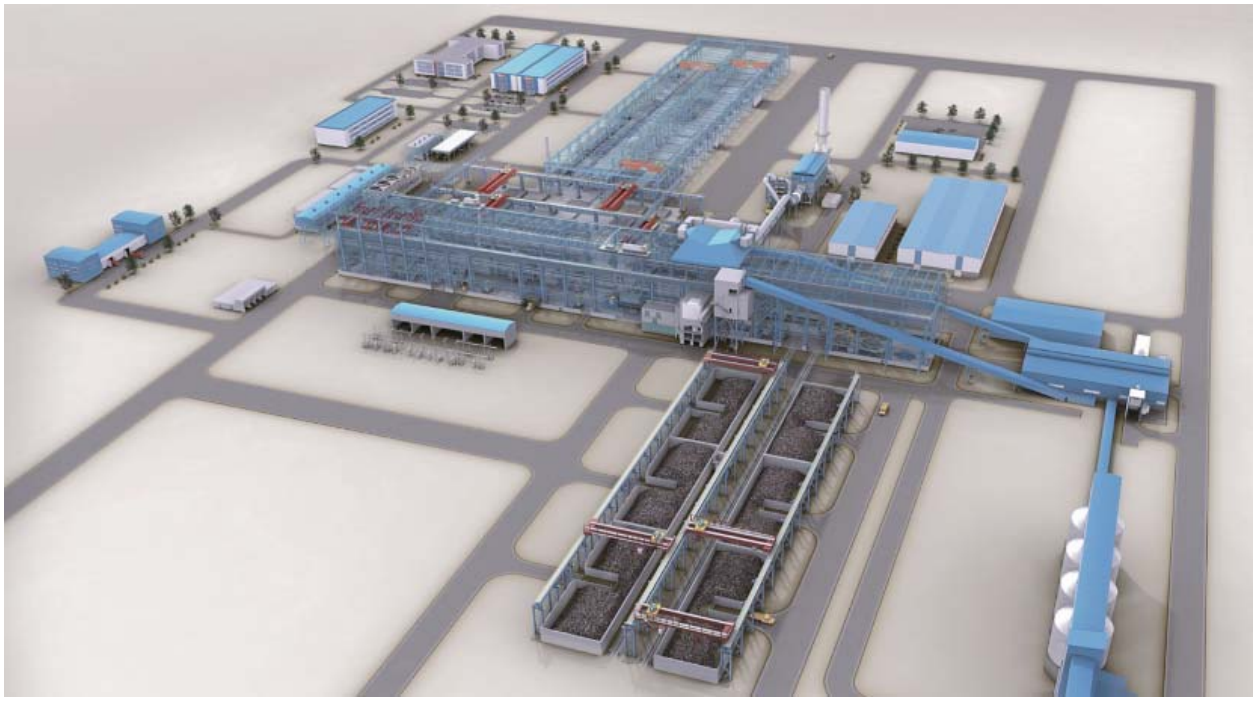

Figure 4 – WinLink based Mini Mill

Besides conventional mini mills, newly developed mini mill concepts like WinLink facility are supported. Using WinLink, billets are directly rolled after casting without storing billets in a billet yard. A combined APS approach for both parts of the production process (melt/cast and rolling) is required to utilize the whole production line in an optimum way.

In case the mill has to deal with many small orders, it can be a challenge for the planning department to do all planning manually. The Scheduling tool is a valuable asset for a long rolling mill to ensure that all orders are properly planned, the production facilities are well utilized and the material demand is effectively managed.

As typically in a long rolling mill the rolled material is not the final product but is cut into required order length before leaving this facility, The APS also calculates an optimum billet/bloom length as an important directive for caster automation to reduce billet scrap and therefore increase the overall yield.

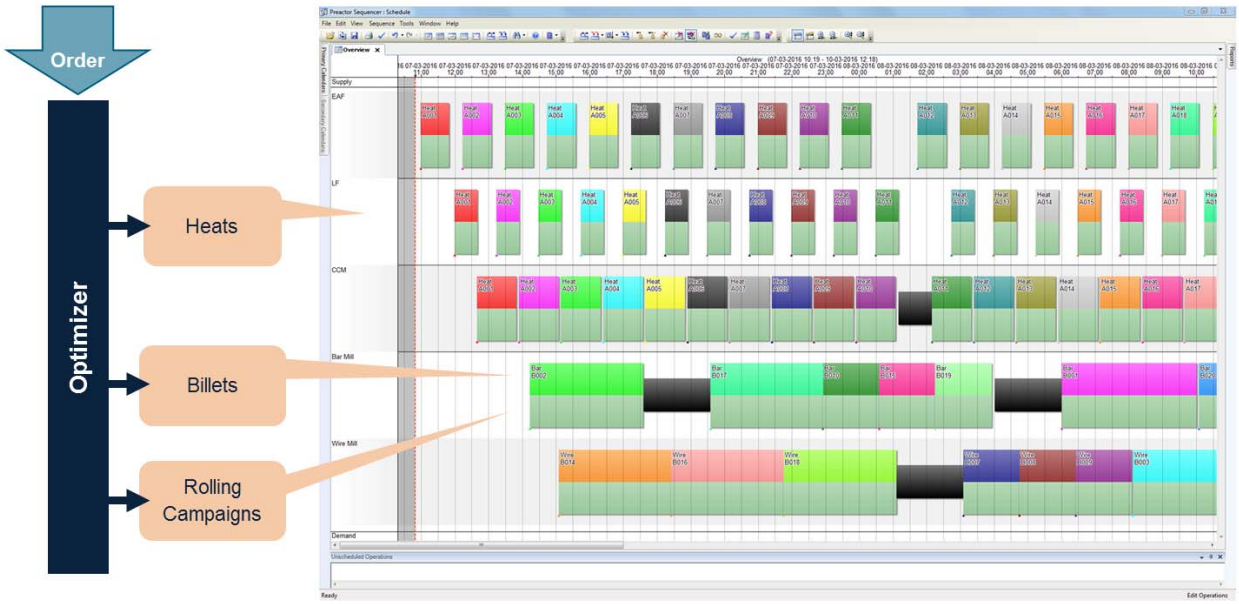

Figure 5 - typical Mini Mill schedule

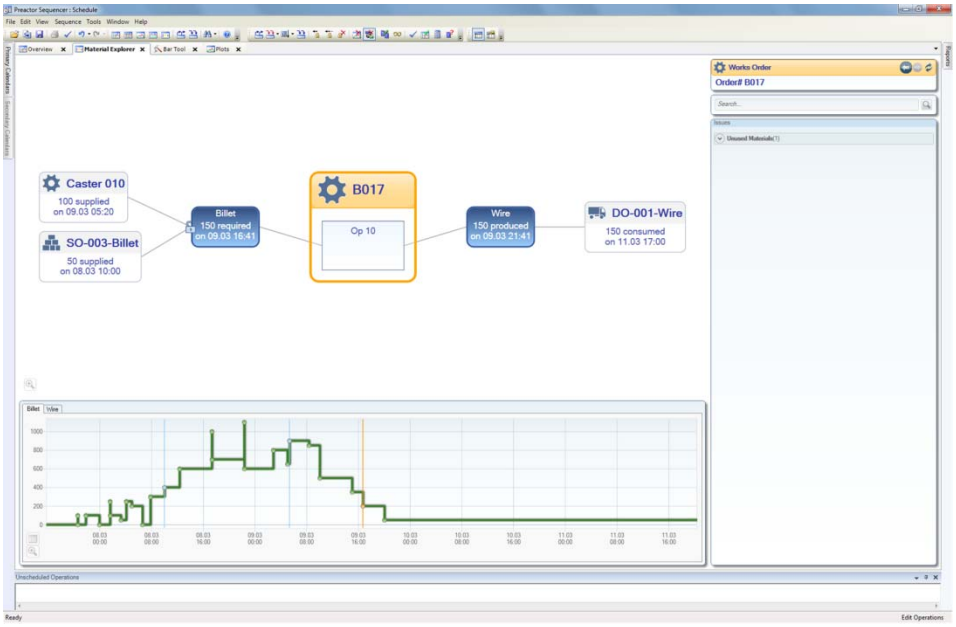

Figure 6 – Material Explorer with material balance and graphical billet inventory

4 CONCLUSION

The APS for customers in metals industry provides significant benefits such as:

- Improved productivity and yield by automated detailed scheduling of complete Production line;
- Full support of “Direct Charging Mode” of ESP & WinLink based Production;
- Online reaction on deviations to planned schedule;
- Seamless horizontal integration with automation systems of production line;
- Vertical integration between Business Level and Production Process;
- High reliability of due date fulfillment;
- Reducing energy costs by considering energy savings related constraints;
- Support the work-to-order concept to minimize stocked products without assigned orders, hence minimizing inventory.