Intelligent Energy and Media Management in the integrated steel mill

Simulation based on Dymola/ Modelica

Abstract

The complex behaviors and dynamic interactions of the integrated steel mill of ThyssenKrupp CSA (TKCSA) have been modeled to improve the management of energy and media. The static and dynamic model design helps to schedule plant operations, shutdowns or maintenance periods, as well as simulate production scenarios to manage the production and consumption of gases (Basic Oxygen Furnace Gas, Blast Furnace Gas) in order to optimize the production of electrical energy and minimize the consumption of natural gas. Thus optimizing the total cost of production, as well as the CO_2 output.

Furthermore the model assist to calculate and forecast the economic cost of the consumptions of natural gas, electric energy and media such as nitrogen, oxygen, compressed air and argon to optimize the planning of short and long term contracts.

Referring to Abstract held at METEC InSteelCon 2011 “Intelligent Energy and Media Management in the integrated steel mill of ThyssenKrupp CSA”.

1. Introduction

Integrated Steel Mill TKCSA

The Energy and Media Solution (EMS) model created for ThyssenKrupp CSA consists of an energy balance of the integrated steel. The integrated steel mill of TKCSA consists of a coke oven, a sinter plant, two blast furnaces, a steel plant with two converters and two casting lines and a power plant. Blast furnace gas (BFG) produced in the blast furnace is utilized partly in the power plant to generate electrical energy and partly utilized in the hot stoves of blast furnace. Basic oxygen furnace gas (BOFG) produced in the converters in the steel plant is partly utilized in the sinter plant, steel plant, and a mixing station which enriches the BFG for blast furnace utilization. This mixing gas station can mix BFG, natural gas (NG) and BOFG to create the calorific value which is needed to fulfill process requirements. Additionally there is a substitute mixing gas station which can mix BFG, NG and nitrogen in case of no availability of BOFG.

2. Energy and Media Solution (EMS)

EMS is a software that consists of an energy balance model which was developed to simulate all dynamic interactions of the integrated steel mill of TKCSA. Based on the different plant production plans, EMS models:

- The consumption of industrial gases in the whole steel mill
    - High and low pressure oxygen
    - High and low pressure nitrogen
    - Argon
    - Compressed dry air
    - Blast furnace air
- Consumption of natural gas in the whole steel mill
- Production and consumption of process fuels (BOFG, BFG)
- Production and consumption of steam
- Generation and consumption of electrical energy
- Cost of industrial gases, natural gas and electrical energy.

Figure 1 shows the model concept, which illustrates all the main units which were modeled and their connections for fuels, industrial gases, steam and electrical energy.

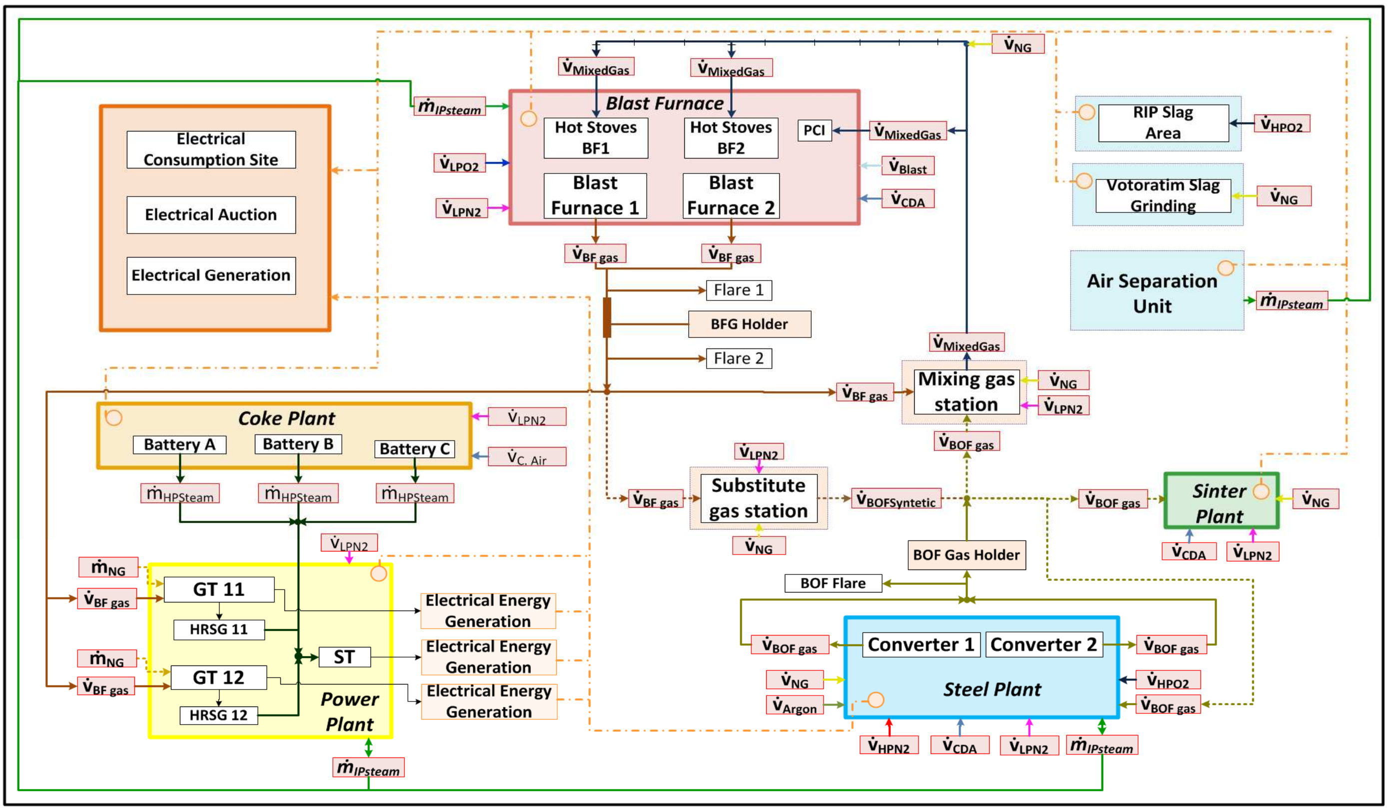

Figure 1: EMS Model Concept

EMS is based on two modules, a static and scheduling module. The static module allows the user to give the production plans for the different plant areas, which after simulating; the software displays static results for the different productions and consumptions. Scheduling mode, allows the user to schedule different plant production plans at different times. In this module the user can schedule not only production plans, but also maintenance periods or planned and unplanned shutdowns. After simulation, the software displays the results for the different productions and consumptions in different periods of time. These results are no longer showed as values like in static module, but as curves which can be displayed graphically in the software.

Additionally, the scheduling mode contains an economic module which analyses the results that are displayed in scheduling mode for industrial gases, natural gas and electrical energy. The economic module takes into consideration the different contract information for flows and prices for industrial gases and natural gas, as well as the different contracts and spot market prices for electrical energy, to calculate their respective costs. Figure 2 illustrates the different modules of the software model.

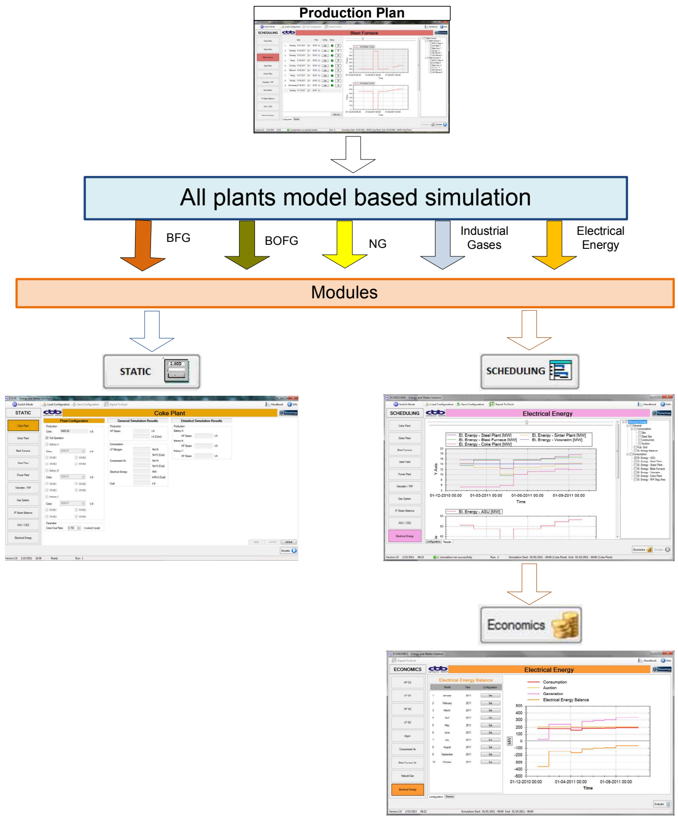

Figure 2: Model Modules

3. Practical Software Implementation

An example is shown below, were the three month production plan (February, March and April 2011) of the steel mill based on steel slab production was configured in the model. This scenario is here called the base line scenario. In order to analyze different “what ifs” production scenarios for the next three months, two additional scenarios were developed. Scenario 1, was configured with the same production plan as scenario base line, but the BOFG holder was disabled for the whole 3 months in case of gas holder malfunction. In Scenario 2, one blast furnace is taken out of operation for the first two weeks of April (01.04.2011-15.04.2011). The production plan of the steel making plant, coke plant, and sinter plant were adjusted to meet total hot metal production for only one blast furnace.

The description for all scenarios can be seen in Table 1.

Base Line Scenario	-Blast Furnace, Sinter Plant, Coke Plant and Steel Making Plant according to production plan for steel slabs.
Scenario 1	- Same production plan as Base Line Scenario. - BOF Gas Holder out of operation for 3 Months
Scenario 2	- One blast furnace shutdown from 01.04.2011 – 15.04.2011 - Due to Blast Furnace shutdown, production plan was adjusted for other plants.

Table 1: Scenarios

Figure 3 shows the steel slab production for base line scenario.

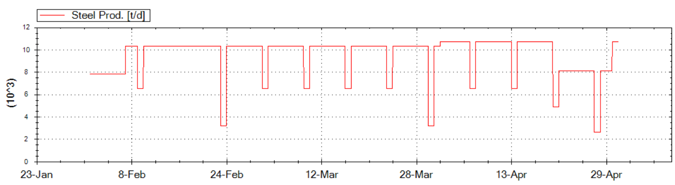

Figure 3: Steel slab production plan for base line scenario.

4. Software Results

The different configurations were given in the model to observe and compare the consumptions and economic costs of industrial gases, natural gas and electrical energy for the different scenarios. Figure 4 below shows the consumption of high pressure oxygen for base line scenario and scenario 2. From baseline scenario, we can observe that during the different periodical maintenance periods of the steel plant, where the production of steel decreases, the consumption of high pressure oxygen also decreases. During these maintenance periods the consumption of high pressure oxygen is below the minimum contracted amount from the supplier. Under this minimum supply flow (take or pay contract), the high pressure oxygen not consumed must also be paid. This is also the case for scenario 2, but additionally there is a longer period of time (during two week blast furnace shutdown) when the minimum supply is not consumed.

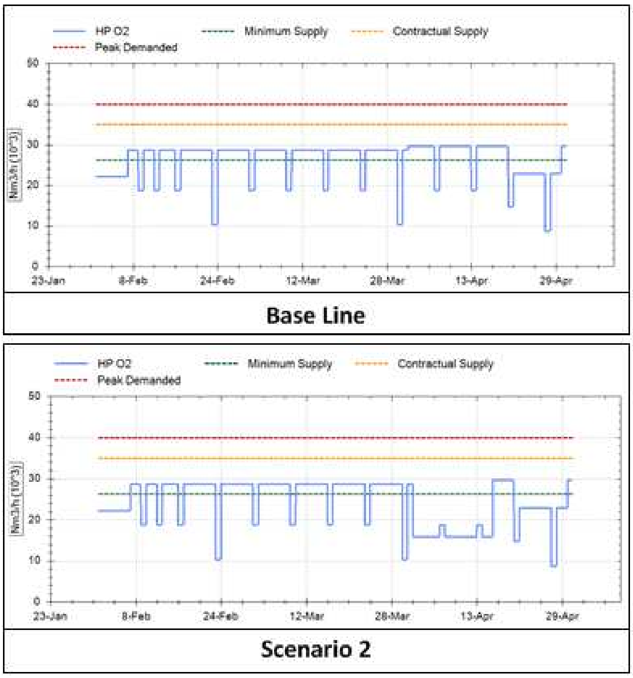

Figure 4: High pressure oxygen consumption

Figure 5 shows the consumption of natural gas for base line scenario and scenario 1. The consumption of natural gas during scenario 1 is noticeably higher in comparison to base line scenario. This is because during scenario 1, the BOFG holder is out of operation and natural gas must be utilized to substitute BOFG.

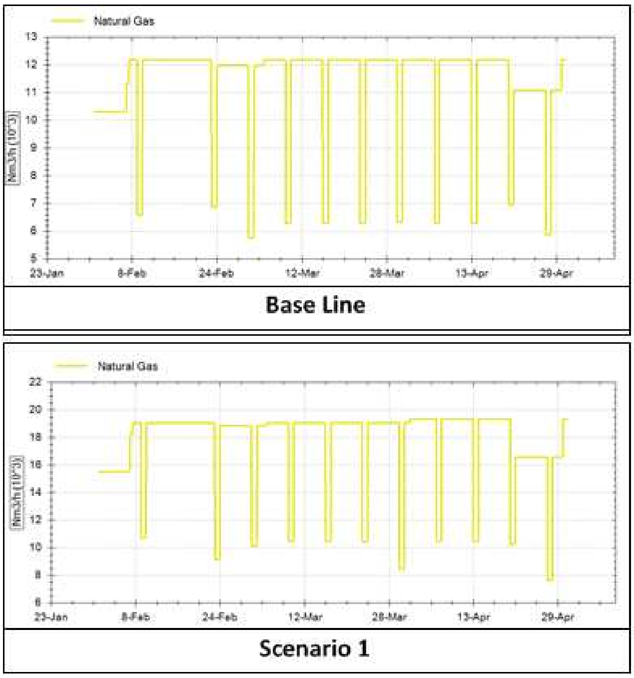

Figure 5: Natural gas consumption

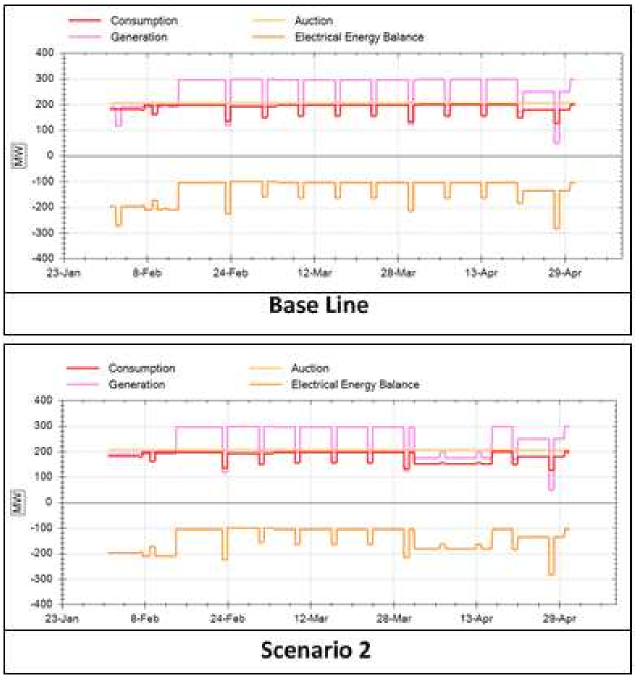

Figure 6: Electrical energy generation and consumption

Figure 6 shows the electrical energy generation and consumption of the steel site. The two graphs in the following figure display:

- The electrical energy generation of the power plant.
- The electrical energy consumption of the whole steel mill.
- The contracted megawatts (206 MW) for the auction.
- The electrical energy balance. This electrical energy balances represents either a surplus or deficit in energy for the steel mill. It is described by: electrical energy generation minus steel mill energy consumption and electrical energy destined for the auction.

In scenario 2, during the two week shutdown of one blast furnace, the electrical energy generation decreases because the availability of BFG from blast furnace decreases. This means less BFG is available for the gas turbines in the power plant, increasing the deficit in electrical energy. The deficit in electrical energy represents an additional cost for the steel mill, as this energy must be bought.

Figure 7 shows a graphical representation of the distribution of costs for all three scenarios.

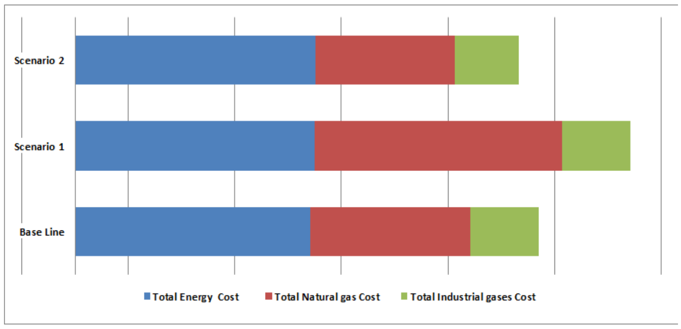

Figure 7: Scenarios cost result and comparison

Figure 7 illustrates that scenario 1 is the most expensive scenario, as the cost for natural gas for this scenario is greater in comparison to the other scenarios. Because of BOFG holder shutdown, more natural gas is utilized to run the different plants to replace BOFG. One would expect, in scenario 2, that because of one blast furnace shutdown the total cost in comparison to base line scenario would be less, as there is less consumption of industrial gases, fuels and electrical energy with one blast furnace not in operation. We can see that the cost for industrial gases is similar to base line scenario, this is due to the fact that the contracts for industrial gases include a take or pay clause. In this case, many not consumed amounts for industrial gases must be paid, making the cost of industrial gases for scenario 2 very similar to base line scenario. At the end, due to the fact that in scenario 2 the total production of steel is less than in scenario base line, as one blast furnace is out of operation for two weeks, scenario 2 is not a solution to be followed

5. Conclusions

EMS is a simulation software developed to improve the management of energy and media. Its scheduling module allows for optimization of the generation of electrical energy and minimization of the consumption of natural gas through scheduling of plant operations, still standings or maintenance periods, through the simulation of different production scenarios.

EMS can be utilized as a decision tool, which though the analysis of different operating scenarios, can calculate and forecast the economic cost of the consumptions of natural gas, electric energy and industrial gases such as nitrogen, oxygen, compressed air and argon to assist in decision making.

EMS also helps to understand the functionality of an integrated steel mill by showing how the operation of one plant can affect the total functionality of the whole steel complex. Currently EMS is being validated as more measured process data becomes available to optimize the calculations of model results.

Furthermore, it is planned to develop an optimization of the carbon dioxide emissions which are developed from the different processes and from the combustions in the different stationary equipment. This planned environmental module will help monitor the amount of carbon dioxide emissions during steel production.

6. Abbreviations

Abbreviations	
EMS	Energy and Media Solution
TKCSA	ThyssenKrupp Siderúrgica do Atlântico
BOF	Basic Oxygen Furnace
BOFG	Basic oxygen Furnace Gas
BF	Blast Furnace
BFG	Blast Furnace Gas
NG	Natural Gas
HPO_2	High Pressure Oxygen
LPO_2	Low Pressure Oxygen
HPN_2	High Pressure Nitrogen
LPN_2	Low Pressure Nitrogen
CDA	Compressed Dry Air
IP	Intermediate Pressure
HP	High Pressure
GT	Gas Turbine
ST	Steam Turbine
HRSG	Heat Recovery Steam Generator
PCI	Pulverized Coal Injector

Table 2: Abbreviations

7. Acknowledgments

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8. References

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