A WATCHDOG SYSTEM FOR ENERGY EFFICIENCY AND CO_2 EMISSIONS REDUCTION

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Abstract

This paper shows real industrial examples in which, with the existing equipment, continuous CO_2 emissions reductions were achieved while optimizing the energy systems by using an on line model.

The importance of including the cost of CO_2 emissions and how it should be taken into account when managing energy systems is explained. Furthermore, the optimization model is useful to perform case studies to evaluate energy system modifications taking into account this aspect.

Several application examples and results corresponding to European refineries are commented.

How to integrate CO_2 emission costs and constraints within the overall energy system on line models and their optimization is also explained.

1. Introduction

Many industries are facing increasing tax pressures to reduce greenhouse gases emission because of their countries adherence to the Kyoto protocol. They are challenged to optimize their energy systems with the goal of maintaining or reducing their CO_2 emissions within a trading market environment but, at the same time, to maintain their competitiveness.

As the utility and energy systems are often the major source of SO_x, NO_x and CO_2 emissions, the control of these emissions and management of credits and quotas are tightly related with energy management.

In the case of refineries, chemical and petrochemical plants, which usually operate complex energy systems, CO_2 emissions introduce an additional factor to the complexity of the energy costs reduction challenge. Moreover, since energy represents usually their main cost after feedstock, its reduction is more of a bottom line business decision than a challenge.

Process plants use different type of fuels, they often operate cogeneration units, their steam networks consists of several pressure levels, there are different types of energy consumers and there are emission limits to be observed. Import or export of electricity in deregulated markets, which could also be traded off with more or less CO_2 and other contaminant gases emissions, increase the optimization problem complexity.

2. A Watchdog for energy system management

In order to successfully address the energy system management, the Visual MESA software is widely used at refineries and petrochemical complexes (Ref 1). It is a Real Time Optimization application that is saving refineries all over the world millions of Euros per year by advising on optimal operating conditions of their utilities systems, comprising steam, fuels, electricity, etc. Visual MESA has been adopted by the leading refiners worldwide and is the first choice in the segment of online energy optimization.

At these sites were Visual MESA is in use, the operators always have available a set of recommendations to operate the energy system at a minimum cost under the current site production scenario. The tool also acts as a "watch dog" since supervisors can evaluate how operators manage the energy system based on the Key Performance Indicators being generated. Prior to applying the optimizing recommendations (or when they are not taken into account) variability in the way the energy system is operated is big and large potential benefits are frequently found. As soon as Visual MESA is commissioned and in use, this variability is noticeably reduced or eliminated, as it was reported by many implementations (see References 2, 3, 4, 5 and 6).

Figure 1 shows an example of the savings found in a refinery during a day of operation (expressed as a % of the total energy costs) when compared with the way operators use to operate without any advisory help. Each point in the plot corresponds to an automatic Visual MESA run. Note the decrease in the potential savings when operators begin to apply the recommendations (last three hours of the day shown). This means that savings are being captured..

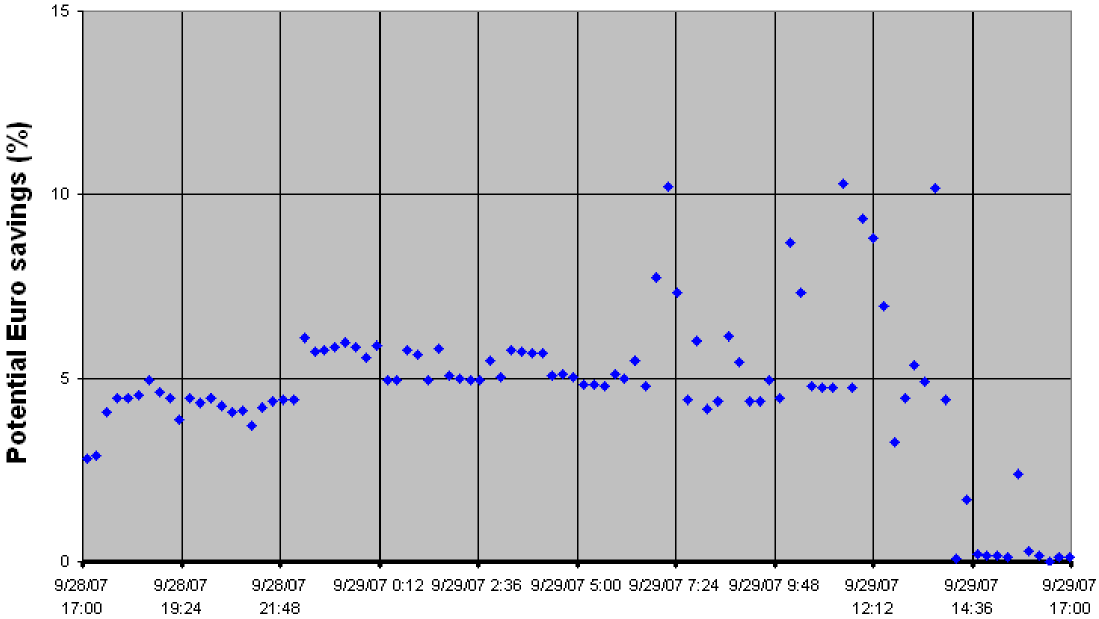


Figure 1. *Identified savings along a day*

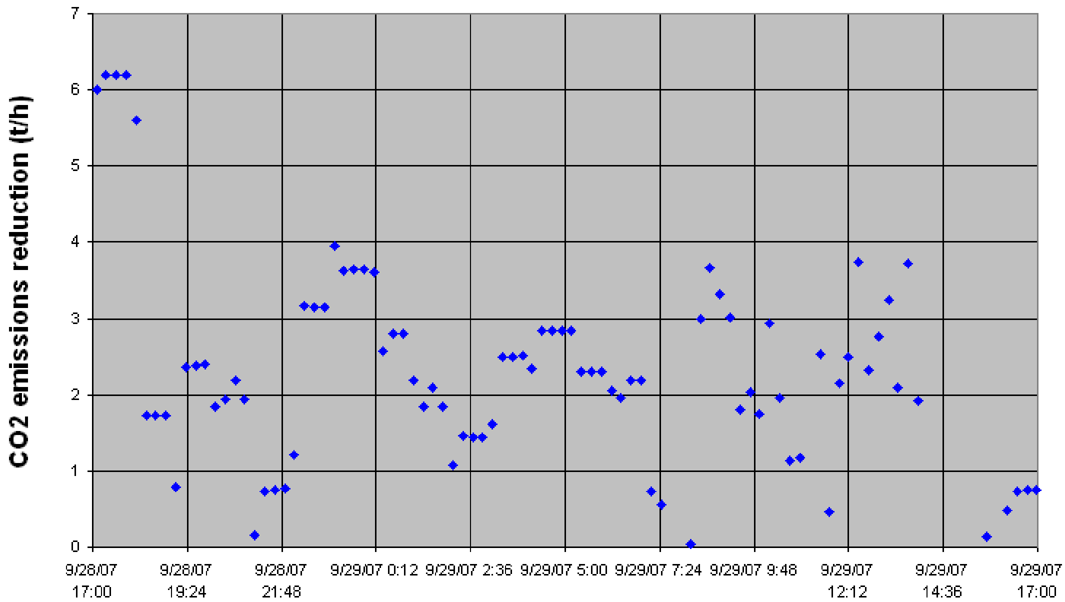


Figure 2. *Identified* CO_2 *emissions reduction along a day*

Figure 2 shows the corresponding potential reduction in CO_2 emissions found for the same example during the same period and the same set of recommendations.

For this particular example, an average of 2 t/h of CO2 emissions savings were achieved (more than 17 Kt/year), helping to obtain also economic savings of 5% over the total energy costs.

3. CO_2 emissions cost in the on line model

The cost of CO_2 emissions is taken into account by the Visual MESA model together with all the other existing purchase and supply contracts of fuels, steam, water and electricity. The CO_2 emissions modeling and economics must be configured according to each site's specific needs.

Thanks to the availability of powerful and versatile calculation blocks within Visual MESA, it is possible to model the emissions factors for each fuel and also the costs and constraints associated to the CO_2 emissions, taking into account all the contractual and operation details of a given site.

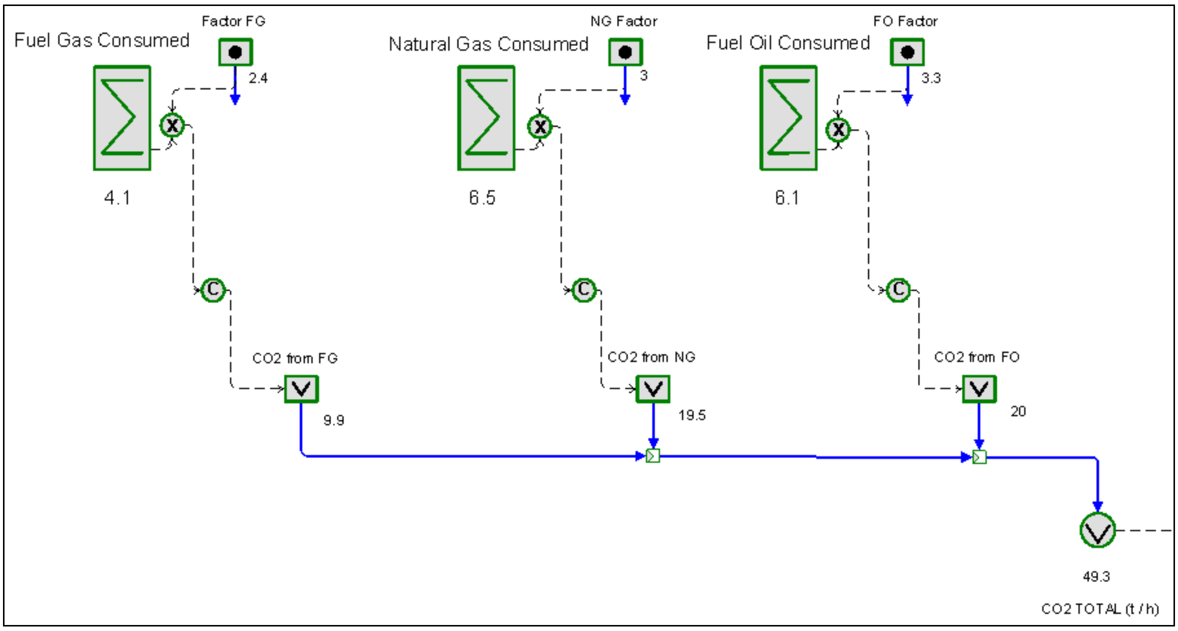


Figure 3. *Details of the* CO_2 *emissions model differentiated by the type of Fuel*

For example, the CO_2 emission cost and total quota constraint can be added to the optimization economical Objective Function (OF) so that, when an optimizer minimizes the OF, CO_2 cost is taken into account together with all the other costs (fuels, electricity, demineralized water, etc.). In this way the optimum fuel feeds to boilers and gas turbines are recommended. Of course, also the limits and/or quotas imposed to other emission gases can be taken into account at the same time.

In general, since the energy cost savings are mainly achieved by a reduction in fuels consumption, the optimization will always imply a reduction in CO_2 emission, except in those scenarios where the optimizer finds the use of a cheaper fuel that generates more CO_2 instead of using a more expensive fuel that generates less CO_2. This could be the case when replacing Natural Gas with a heavy liquid fuel. This challenging tradeoff is affected directly by both the CO_2 allowance price and the annual emission quota.

The following sections explain the importance of including the cost of CO_2 emissions and how it should be taken into account when managing and optimizing the energy systems. Furthermore, it is shown how an optimization tool like Visual MESA helps to perform case studies to evaluate energy system modifications taking into account this aspect.

The consideration of CO_2 emissions in the energy system model for everyday usage, to perform the energy system Real Time, On Line, Optimization, is also explained.

3. CO_2 emissions accounting

In many countries, a given industrial complex has an assigned quota for total CO_2 emissions. They periodically report the total generated CO_2 related to fuels consumptions and operating processes. At the end of the year, if the quota is exceeded, each ton of CO_2 emitted above the quota has to be paid at a given market price. For instance, the price may be referred to the European Union Allowance (EUA), equivalent to one metric ton of CO_2 emissions (see http://pointcarbon.com).

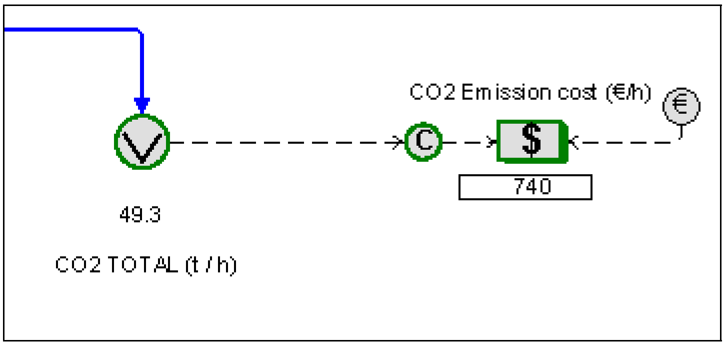
In some countries, there is an additional tax, sometimes much more expensive than the allowance price, as a penalty for having exceeded the quota.

Also, if emissions are below the quota, the tons of CO_2 saved can be sold at the market price of the emissions allowance.

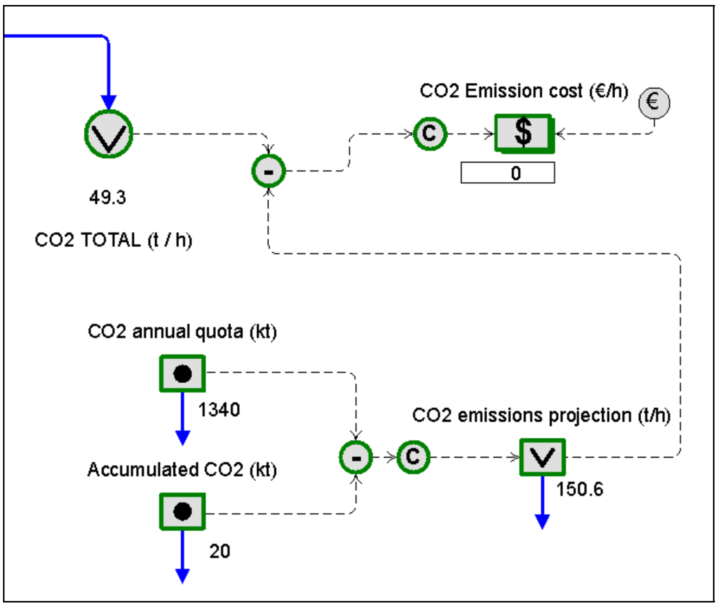
4. How CO_2 emissions impacts global energy system optimization

The cost of CO_2 emissions in the OF can be incorporated in several different ways depending on whether the quota has been exceeded or the accumulated emissions are below the quota, at a given point of time and over a given accounting period (generally one year):

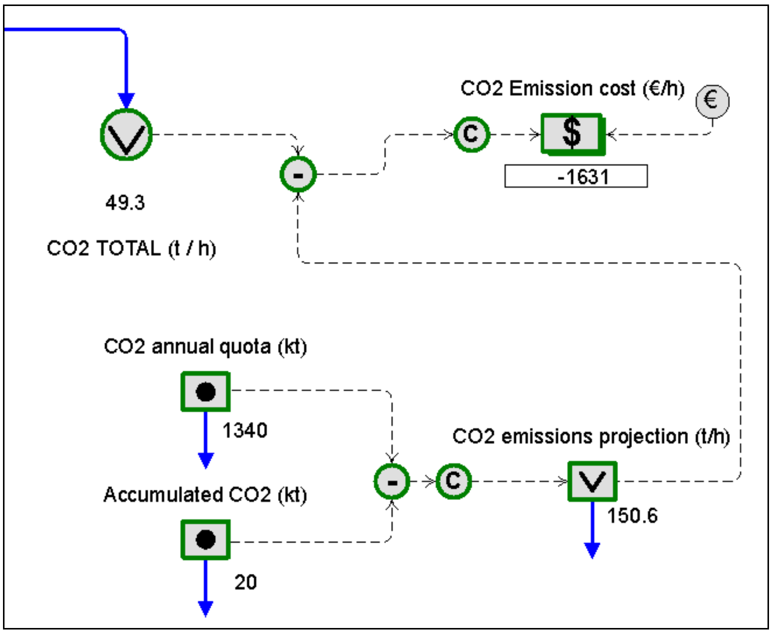
a) *For each ton of CO_2 emitted a price equal to the emission allowance price is assigned (plus the applicable taxes).* This approach is not fully realistic from the accounting perspective, unless the plant has exceeded the CO_2 emissions quota. However, it assures that the optimization will be always focused on minimizing CO_2 emissions. This approach may influence the optimization results in those cases that a compromise between using a more expensive fuel with less CO_2 emissions and a cheaper fuel with more CO_2 emissions exists. It will, in fact, penalize the cheaper fuel.



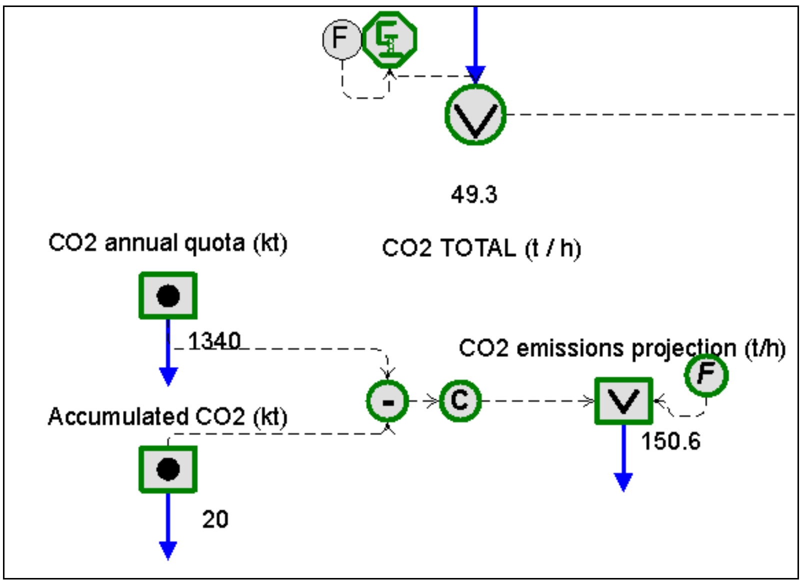
b) *No cost is assigned to the emitted CO_2 until the quota is achieved.* In this option, if there were compromise solutions between the use of a more expensive fuel with less CO_2 emissions or a cheaper one with more emissions, the optimization would advise the second. Consequently, the quota will be achieved early in time. This approach should be only applied in those plants where, due to its particular operating conditions, the annual quota is unlikely to be achieved.



c) *The CO_2 emissions have always an associated cost, however it will depend on the emissions projection for the rest of the period (typically one year).* If this projection of emissions estimates that at the end of the period the quota will not be reached, each ton of CO_2 below the quota will have a negative cost (-) equal to the price of sale of the emissions rights, which for optimization purposes will correspond to a credit (assuming this emissions rights not used will be able to be sold). If the projection foresees the quota will be reached, the price will be equal to the cost of emission (plus the applicable taxes).



d) *In all cases a constraint can be imposed on the current CO_2 emissions*. Such a constraint should be to be equal to the projection of the future emissions calculated in such a way that the quota would be met at the end of the considered period (i.e., end of the year). This approach would help manage the fuels consumption so that the site is always below the emissions quota in order and therefore take the maximum advantage of the quota at the end of the considered period.



If the quota eventually is exceeded before the end or the period, the additional CO_2 emissions cost will be included in the Objective Function to be minimized. Under this scenario the price of each ton of emitted CO_2 will be equal to the CO_2 emissions allowance (plus the applicable taxes).

5. Industrial examples

5.1. Day to day CO_2 emissions reduction

The first real industrial example corresponds to TOTAL Feyzin refinery (Ref 7). TOTAL is a leading refiner-marketer operating 11 refineries directly in Western Europe. The reduction of greenhouse emissions and the enhancement of energy efficiency are among the Company corporate challenges.

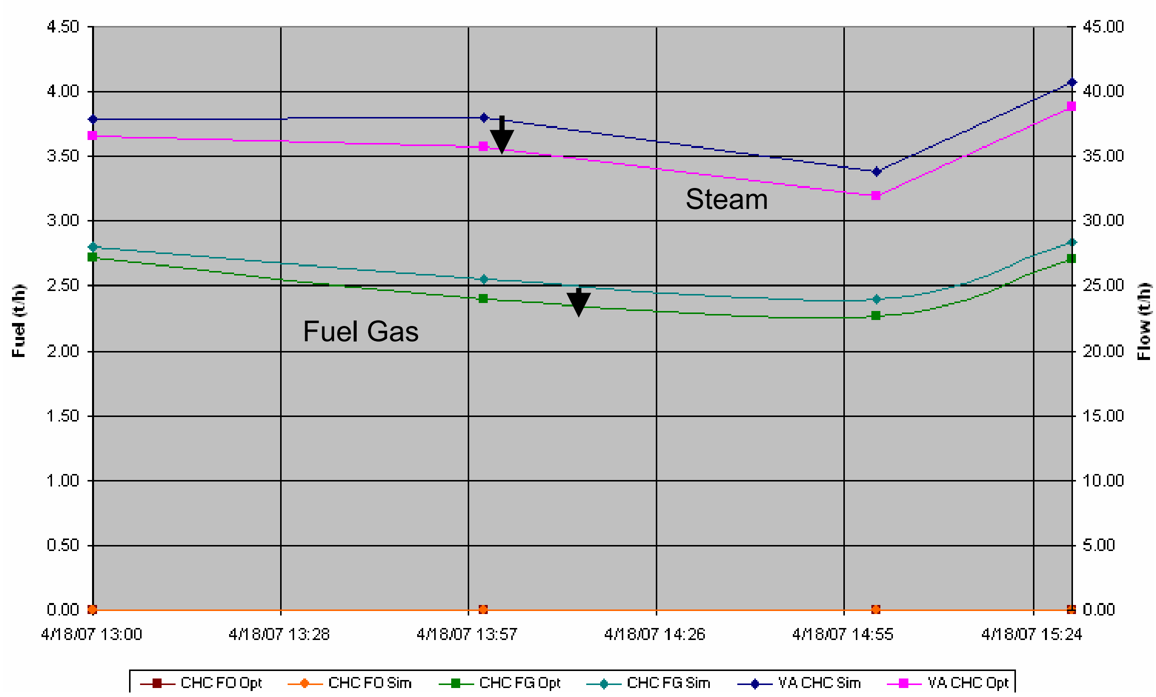
In this example, a set of manual operating recommendations given by the optimizer during a Shift have been:

- Pump swaps
- Fuels to boilers (i.e., FG and FO)

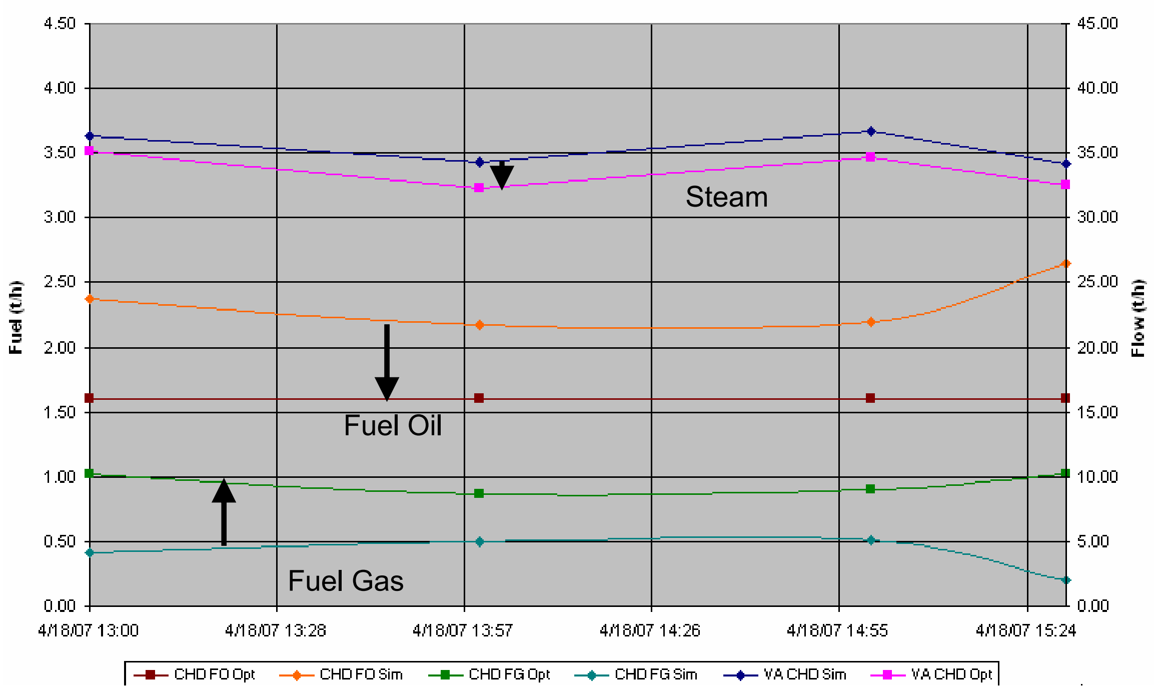
As a result of the manual actions, the changes performed by the control system have been:

- Steam production at boilers
- Letdown and vents rates

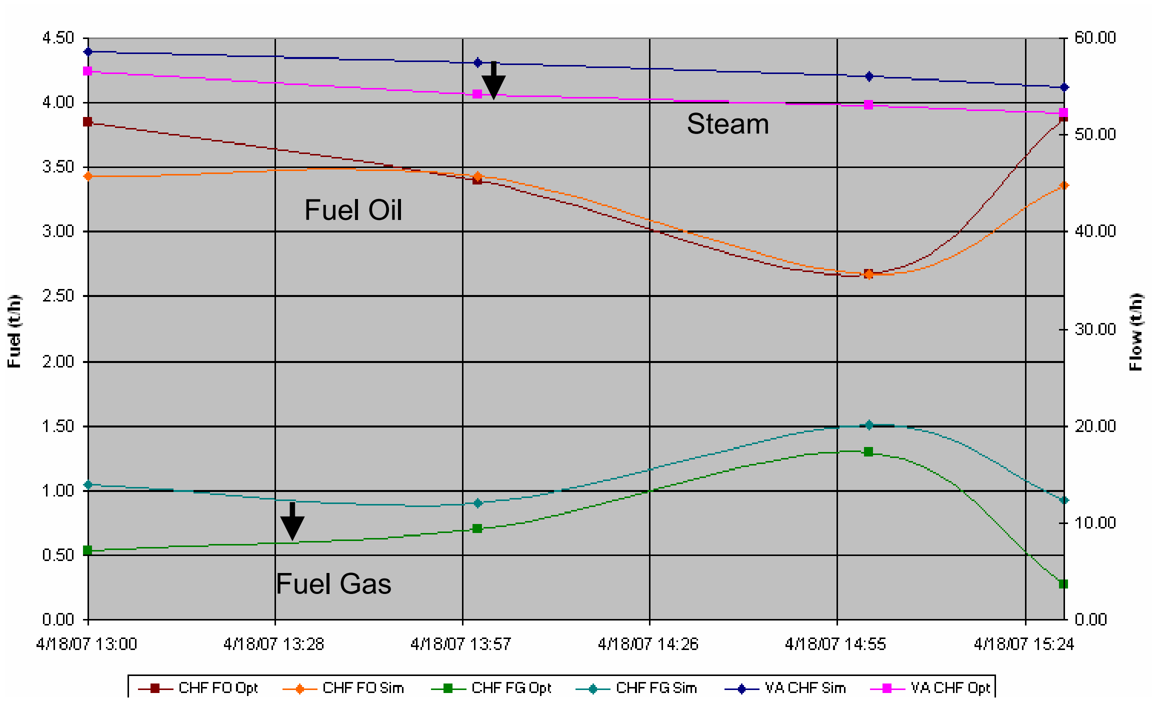
The following figures show the impact on steam production, fuel use and CO_2 emissions reduction.



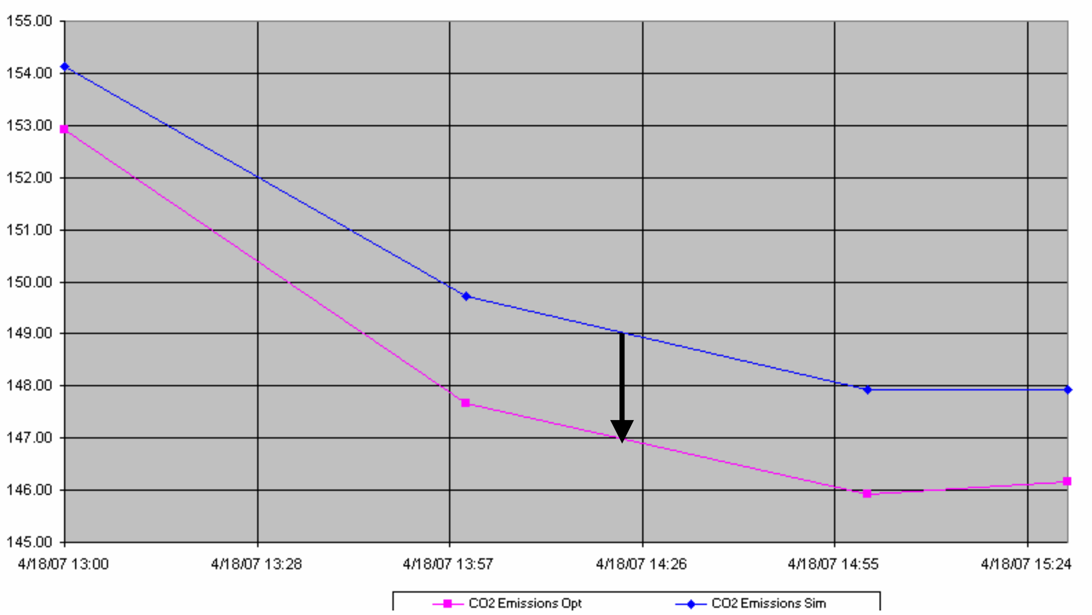
Boiler C (100% Fuel Gas): 2 t/h less of steam



Boiler D (FO and FG): 2 t/h less of steam) and FO to the minimum



Boiler F (FO and FG): more than 3 t/h less of steam



CO_2 emissions: 2 t/h less

In summary,

- Almost 1 t/h less of FO consumed
- Approx 7 t/h less of high pressure steam produced
- Approx 2 t/h less of CO_2 emitted
- Approx 200 kW more of electricity imported

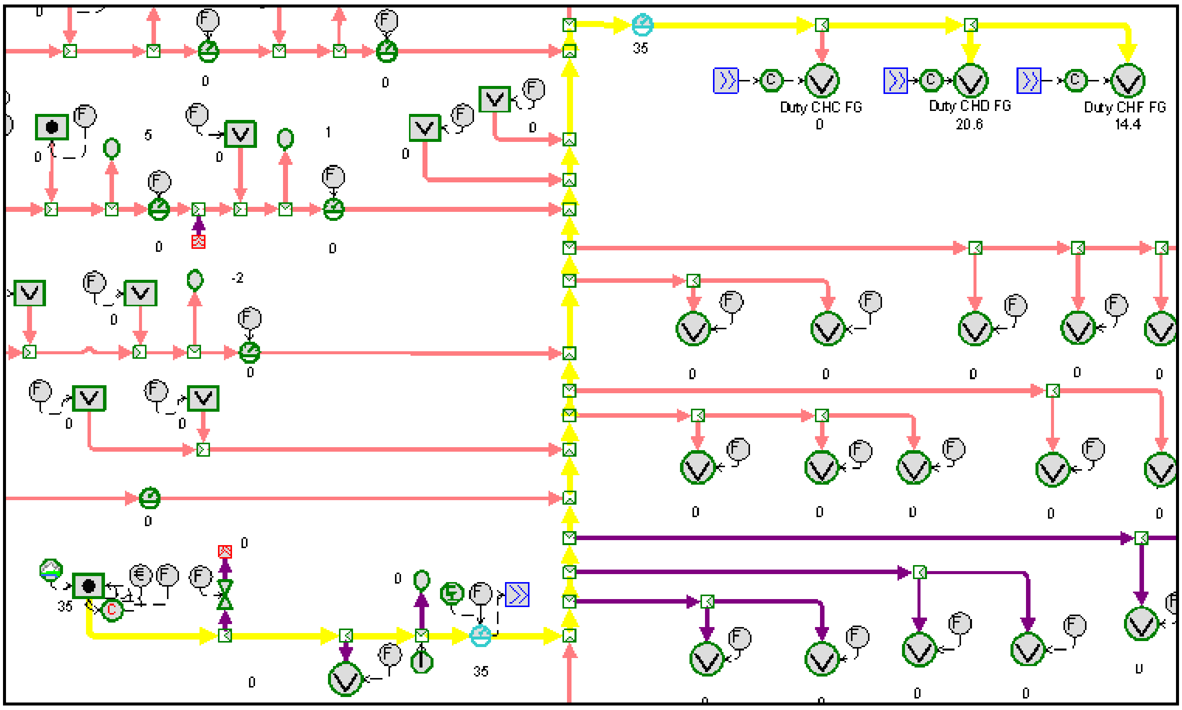
5.2. Fuels choice

When considering the CO_2 emission cost, the following is an example of the recommendation for operators:

- Fuels to boilers

As a result of the manual change in the boilers fuels diet (more FG and less FO in the overall), the Fuel Gas header pressure control system made the necessary adjustments which resulted in the need to increment Natural Gas import.

The following figure shows the fuel gas network model representation highlighting the differences between current and optimized situation (delta view, duty flows).



On the left, fuel gas suppliers are represented while on the right Fuel Gas consumers are displayed. The values indicate the corresponding change, expressed in MW, after the application of the recommendations (zero value means no change).

As a result of replacing FO by FG (with the need to import more Natural Gas), CO_2 emissions are reduced in 4.7 t/h. This is important to be considered when there is a trade-off between cheaper fuels that produce more CO_2 and more expensive fuels that produce less CO_2. This is very important when the CO_2 emissions quota is expected to be exceeded by the end of the year.

5.3. Investment evaluation

This third example corresponds to a Repsol YPF refinery (Ref 4). Repsol YPF is the largest petroleum refiner in Spain and Argentina, also conducting operations in Peru and Brazil.

The evaluation of the economical impact of adding a new Natural Gas line feed to the Gas Turbine has been done. This investment project would allow the replacement of its Gas Oil feed.

It can be done by simply changing the fuel to the gas turbine and running Visual MESA in What If mode. By running this What If study significant savings have been identified and CO_2 emissions reduction as well.

8. Conclusions

Real industrial examples have been presented in which, with the existing equipment, CO_2 emissions reduction were achieved while optimizing the energy system using an on line software tool.

Optimization is configured to give recommendations to operations personnel on a daily basis. CO_2 emissions cost has been taken into account in several ways, each one adapted to the each site's particular operation needs.

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