Diego Ruiz and Fernán Serralunga, Soteica Europe SL, Spain, and Gian Luigi Diana, Pinuccio Floris and Francesco Mallica, SARAS SpA, Italy, demonstrate how a reduction in energy costs was achieved at the SARAS refinery complex.

MAKING THE MOST OF IT

In a complex refinery, energy costs are highly dependent on the different utility sources used. In order to optimise the heat and power system of its refinery, SARAS implemented Soteica Visual MESA software,[1–7] which was commissioned at the end of 2010. The objective was to minimise costs through open loop recommendations that are provided in real time to control room personnel, while spreading the awareness of economical drivers into the organisation.

Different economic trade offs provide many challenges when operating a site wide energy system at minimum cost. For instance, the optimal electric power generation may depend on power and fuel prices; refinery fuel gas availability; the ability to generate on backpressure, extraction or condensing steam turbines; and steam demand on the different pressure headers.

In the SARAS case, a detailed model of the steam, fuels, electric, boiler feed water and condensates systems was built, contemplating all the real constraints and degrees of freedom for their operation. Such a model is continually fed and validated with live data. Key performance indicators such as equipment efficiencies are noted and stored, and recommendations given by the model are taken into account on a daily basis. The online model is also used in standalone mode to perform case studies for planning how to better the operation of the energy system.

Project activities

The implementation was performed from the end of 2009 until the end of 2010, and the system has been continuously running since that point.

Schedule

The project schedule can be summarised in the following steps:

- Start up.
- Control system review.
- Off site building.
- Mid point review.
- Burn in period.
- Commissioning visit.

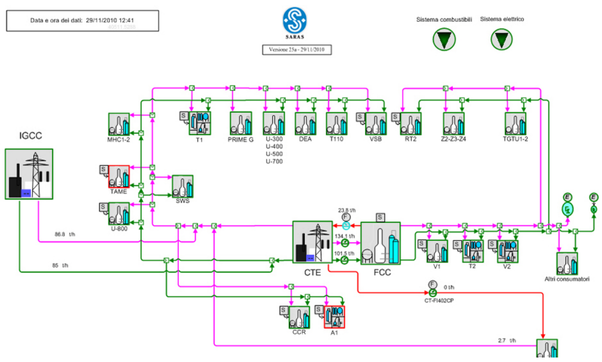

Figure 1. SARAS Visual MESA model main view.

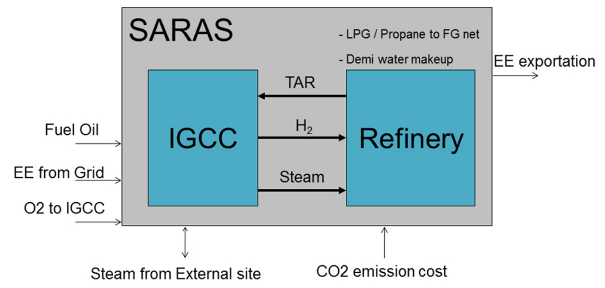

Figure 2. Boundaries of the energy system optimisation.

Start up

Data collection includes the utilities system diagrams, with the location of the available tags measurements from the real time database (historian) and equipment data sheets. Software installation and connection to the plant information system was done at the beginning of the project.

Control system review

A review of the steam, power and fuel control systems with knowledgeable experts was performed. The goals of this control system review were:

- Develop a list of variables that are already controlled and how the software needs to relate to them.
- Identify any new control strategies needed or changes to existing strategies to implement optimisation.

As a result, the optimisation suggestions can be achieved properly through the existing operating and control procedures.

Model building and optimisation configuration

A complete model of the overall energy system was built. The model included the whole fuel, steam, boiler feed water, condensate and electrical systems. SARAS operates an integrated gasification combined cycle (IGCC) power station, which is integrated with the refinery. The gasification feed stream is tar (heavy residue from visbreaker unit), and the plant produces, along with electric power, hydrogen and medium and low pressure steam that are used by the refinery. The complex (refinery plus IGCC) is optimised as a whole, minimising the total operating cost.

The three steam pressure levels, as well as all the utilities and process units, were modelled with a high level of detail, including all the consumers and suppliers to the respective steam, boiler feed water and condensate headers. Details of electricity contracts were also modelled in detail. The fuel system was also modelled, taking into account all its constraints and degrees of freedom, as it is involved with the steam and power generation equipment. Figure 1 shows the main view of the graphical user interface of the model, where the different process unit areas can be observed.

The scheme showed in Figure 2 illustrates the main boundaries of the optimisation. All the inlet and outlet streams have a price that takes part in the objective function. Although tar is an internal stream, it also has a price, as it can be used as a feed for other refinery processes.

The objective function that the software optimises is the total operating cost of the system, which is:

$$\text{Total operating cost} = \text{Total fuel cost} + \text{Total electric cost} + \Sigma\ \text{Other costs}$$

The optimiser's job is to minimise this objective function subject to operating constraints in the system.

- Total fuel cost: determined from the fuel use of each boiler and heater multiplied by their respective fuel prices. Fuels in use correspond to internal production: fuel oil and fuel gas, with a makeup of LPG and propane.
- Total electric cost: composed of the electricity purchased from the grid and also the negative cost represented by the electricity (produced at IGCC) that is exported multiplied by the corresponding prices. It takes into account peak and off peak period pricing, and penalties for deviations from contracted conditions.
- Other costs: correspond to the demi water make up to the system, the CO_2 emissions cost, the cost of the steam purchased from an external site, and the cost of the feed for the IGCC (the O_2 and tar).

The optimisation variables (approximately 60 in total) are mainly:

- Fuel oil/fuel gas to fired boilers and fuel gas to CO boiler.
- Fuel oil/fuel gas to process furnaces.
- Turbo generators management (extraction/condensing steam turbines producing electricity).
- Pump swaps (steam turbines/electrical motors switches).
- Steam importation from an external site.
- Related variables to IGCC operation (tar, steam and power production level, syngas duct burning on heat recovery steam generators).
- Electricity importation.
- LPG/propane make up to fuel gas system.
- Fuel gas flaring.
- Steam letdown and vents.

The constraints (approximately 25 in total) are:

- Minimum and maximum operability of steam generators.
- Minimum and maximum capacity of fuel oil/fuel gas burners.
- IGCC constraints.
- Utilities demand from process plants.
- Refinery (purchase) and IGCC (export) power contracts.
- Hydrogen demand from refinery (coming from IGCC).

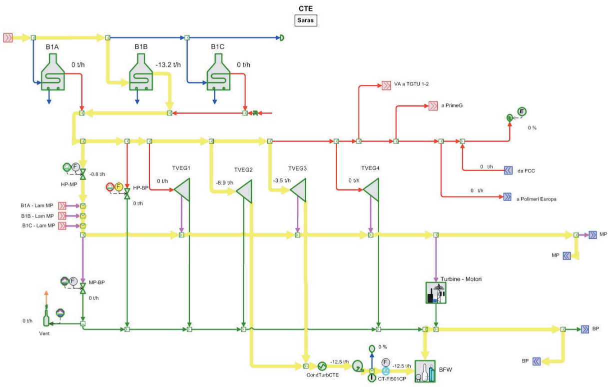

Figure 3. Delta view (optimum minus actual).

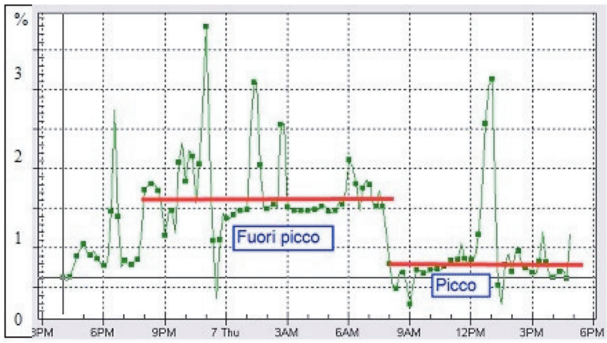

Figure 4. Energy cost reduction throughout a day, with different periods for electric prices.

Visual MESA optimisation is organised into four levels:

- Level 1: includes basically the pressure control related devices, such as boilers, letdown valves and vents.
- Level 2: adds the optimisation of other continuous variables, including turbo generator and extraction/induction/condensing turbines.
- Level 3: adds turbine motor switching optimisation (i.e. discrete variables).
- Level 4: adds equipment that would create 'heartburn' if equipment moves were to be made, such as running a crude distillation feed pump with a turbine, with a motor standby, or equipment that cannot be optimised daily due to the involved risks of the change. Running at level 4 can incur the cost of an 'insurance policy'.

A well tuned model would generally be run at level 3, with a run at level 4 once in a while to evaluate potential operational changes.

Mid point review

The model and optimisation configuration was reviewed with users. Training at engineering and users' level was performed, including the following items:

- Basic skills (model navigation and access to the information).
- Optimisation.
- Monitoring capabilities.
- Case studies ('what if?' planning).
- Building models.
- Building custom reports.
- Software architecture.

Burn in period

Model fine adjustment and an optimisation results analysis are performed on a daily basis. Minor model modifications and addition or adjustment of constraints are undertaken. After all, the operators will ultimately use the tool every day.

Commissioning visit

The model is in use for site wide costs minimisation and as the energy watch dog. Economic benefits already obtained are commented and improvements for the future are discussed.

Software architecture

The model receives live plant data from the historian via a standard object linking and embedding (OLE) for process control (OPC) interface. The software is installed for two types of uses: standalone use (engineering station) and client server use (operators and managers stations):

Client server use

The purpose is to share the solutions, supporting multiple users. Visual MESA server runs as service on a server computer. It automatically runs every 15 mins with no interruption, writing results on the plant information system and generating reports. Any PC connected to the plant network can be configured to access the model and the reports. Users can connect in many ways (HTML, Excel, graphical user interface).

Standalone use

The purpose of this installation is for individual users to be able to run case studies on their own PCs, using a snapshot of the current model (or any other model the user may have built) and the current data or historical data (automatically taken from the plant information system via standard OPC historical data access).

Results

Visual MESA is helping to reduce energy costs by:

- Optimisation: it helps to find the most economical way to run with what the refinery has, while remaining within actual operating constraints.
- Monitoring: it helps to access data, control data quality, follow up key performance indicators, identify imbalances and alert changes to the energy system.
- Case studies: it allows users to perform and evaluate 'what if?' cases to find ways to operate more efficiently and at less cost, including planning and new investments.

Optimisation

The following examples illustrate the day to day use of the online model to reduce energy costs.

Coordination between IGCC and refinery operation

The balancing of the use of the steam among the two main areas (IGCC and refinery) and the corresponding electricity generations are shown to be important in order to reduce the total energy cost of the whole site. It requires some coordination efforts that are usually challenging. The operator's report from the software included the following recommendations:

- More low pressure (LP) steam from IGCC to the refinery (less LP steam to IGCC turbines, 22.7 t/hr).
- More medium pressure (MP) steam from refinery boilers to the network (by increasing steam extraction at one of the refinery's turbogenerators, 21.3 t/hr).
- Less high pressure (HP) steam from refinery boilers to the network (by reducing the steam use of the other turbogenerator that discharges to this level, 22.1 t/hr).
- As a result, more electricity is generated at IGCC (1.5 MW), while refinery electric production is kept almost constant.

Figure 5. Example of a boiler efficiency trend.

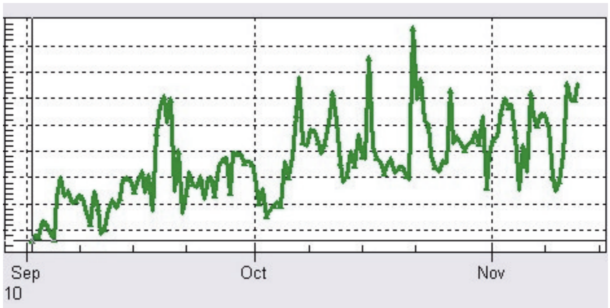

Figure 6. Example of steam imbalances trend.

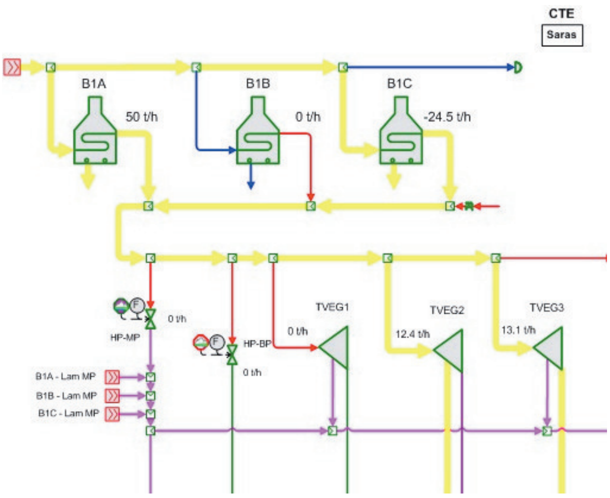

Figure 7. Delta view corresponding to a boiler start up 'what if?' plan.

The order of magnitude of this identified energy cost reduction is 3% of total energy cost.

Steam savings, steam letdown and condensing reduction

The improvements in the management of steam turbogenerators help in the reduction of steam letdown and steam condensing, together with savings in steam production. The operator's report from the software included the following recommendations:

- Reduce the load of one of the refinery turbogenerators (17 t/hr).
- Increase MP steam extraction at one of the refinery turbogenerators to reduce condensing at 12 t/hr (and letdown HP – MP steam).
- Reduce 14 t/hr LP steam to IGCC turbines (it implies a decrease of 1.4 MW of IGCC electricity production).

The order of magnitude of this identified energy cost reduction is 4% of total energy cost.

Fuels system management

In addition to the mechanism of optimisation already described, the optimal management of fuels represents another source of benefits. The operator's report from the software included the following recommendations:

- Increase fuel oil to fired boilers (0.76 t/hr) in order to reduce propane to fuel gas net.
- Increase the load of one of the refinery's steam turbogenerators (MP extraction) to reduce HP to MP letdown (5.4 t/hr).
- Reduce the load of the other two refinery turbogenerators so less LP steam is given to IGCC turbines (increase of LP steam from IGCC to the refinery by 10.5 t/hr).

The order of magnitude of this identified energy cost reduction is 3% of total energy cost.

Electricity system management based on market/contract prices

One important aspect of the energy system management is the fact the electricity pricing can change throughout a given day. In this case, two periods are clearly differentiated (peak price and off peak period), allowing different optimisation strategies.

Figure 3 shows the delta view (highlighted in yellow and displaying the differences between optimum and actual values) corresponding to the power plant. The observed recommendations are related to:

- Minimising condensation in the steam turbogenerators.
- Consequently, a reduction in steam production at boilers (FO use) and an increase in electricity importation will be observed.

Identified energy cost savings with respect to total energy cost are approximately 0.75% during the day (peak electricity price) and more than 1.5% during the night (Figure 4).

Monitoring

Different key performance indicators are recorded, such as energy system economics, equipment efficiencies and steam headers imbalances. Figure 5 shows the trend of one of the fired boiler's efficiencies.

The long term trends help to identify those pieces of equipment that can lose efficiency and therefore justify cleaning, when possible. Also, the headers imbalances are often related to sensor failures. A sudden increase of an imbalance would trigger the search for the cause. If a bad signal sensor or an out of range signal were identified, it would need to be repaired and/or reranged. Figure 6 shows an example of an imbalance trend.

Case studies

Different case studies have been undertaken using the model. One example centred on evaluating how to operate the energy system after the start up of a fired boiler. Figure 7 shows the delta view in this case (highlighted in yellow, displaying the difference between comparison case and base case).

Here, the optimiser helped to determine which boiler load to decrease and which steam turbogenerator load to increase in order to manage the new situation (after boiler B1A start up) at the minimum energy cost.

Conclusion

An online model has been successfully implemented at SARAS refinery complex and is now operating to help reduce the energy costs. The sitewide energy cost minimisation has been achieved, and an awareness of important economical drivers has been propagated throughout the organisation.

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