Real-time refinery energy management

An online model installed at Repsol Cartagena refinery enables optimal balance between internal energy production and demand

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Repsol Cartagena was the first oil refinery to be built on the Iberian Peninsula. It has an annual crude distillation capacity of 5.5 million tonnes, with two main areas of production: fuels; and lube oils, asphalts and paraffinic and aromatic oils. Repsol Cartagena is currently involved in an ambitious expansion project, whereby 22 new units will be built, increasing its refining capacity to an annual 11 million tonnes.

An online model has been installed to monitor and optimise the energy system, using technology that has been applied successfully by Repsol in similar projects.[1-4] A detailed model of the steam, fuels, electricity, boiler feed water and condensate systems has been assembled, including all interactions between these systems, as well as real plant constraints and degrees of freedom of operation. The model is scheduled to perform automatic executions to optimise the entire system, and it is continually populated with validated live data obtained from the process.

A calculation of equipment efficiencies is carried out as part of the performance-monitoring activity of the model. Other monitoring aspects include continuous auditing of the energy system so that data can be relied on for evaluating the value of energy production and usage to reduce or eliminate waste.

Recommendations supplied by the model can be taken into account by operations on a daily basis. The same model used for online, real-time optimisation can also be used in standalone mode, populated either with current or historical data, to perform case studies for planning or to evaluate alternatives for better operation of the energy system. As a result of the project, information relating to the refinery's energy system has been organised into one model and a single environment, to which everyone has access.

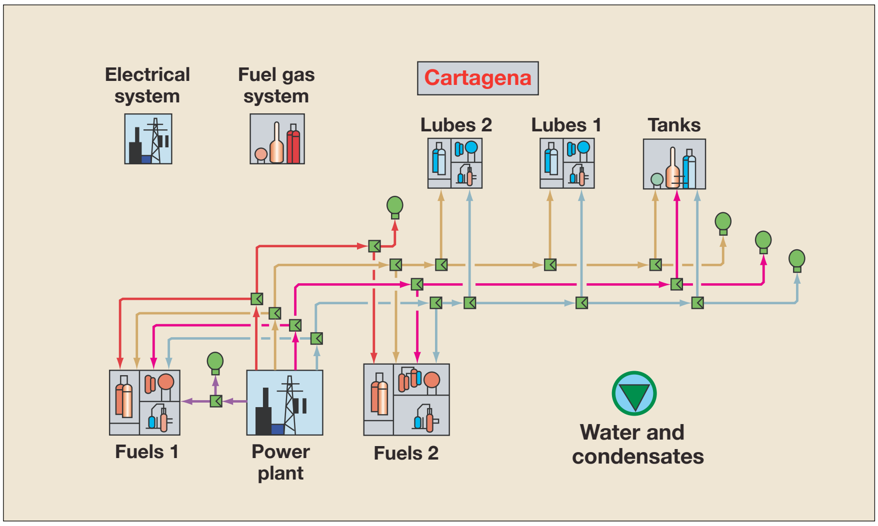

Figure 1 Repsol Cartagena energy system: top view from the Visual MESA model GUI

Furthermore, the project has enabled an understanding of all of the decision variables and their associated constraints, which are sometimes hidden or ignored. Additionally, the centralisation of responsibility for optimal operation of the energy system has been established. A proactive support programme with the aim of ensuring that the benefits of the project are sustained and that the health of the model is kept in check over time is also under way.

Different economic trade-offs provide many challenges to site-wide operation of the energy system at minimum cost

Refinery energy system

The energy system is based around five steam pressure levels, with four fired boilers producing high-pressure steam, a cogeneration plant producing steam and electricity, and a set of steam turbo-generators producing electricity. Different economic trade-offs provide many challenges to site-wide operation of the energy system at minimum cost, such as the trade-offs among electrical power, steam and fuels networks. In addition, the Kyoto protocol has introduced new motivation to calculate and reduce CO_2 emissions.

Figure 1 shows a main view of the Visual MESA model graphical user interface. By double-clicking on the respective icons of each plant area,

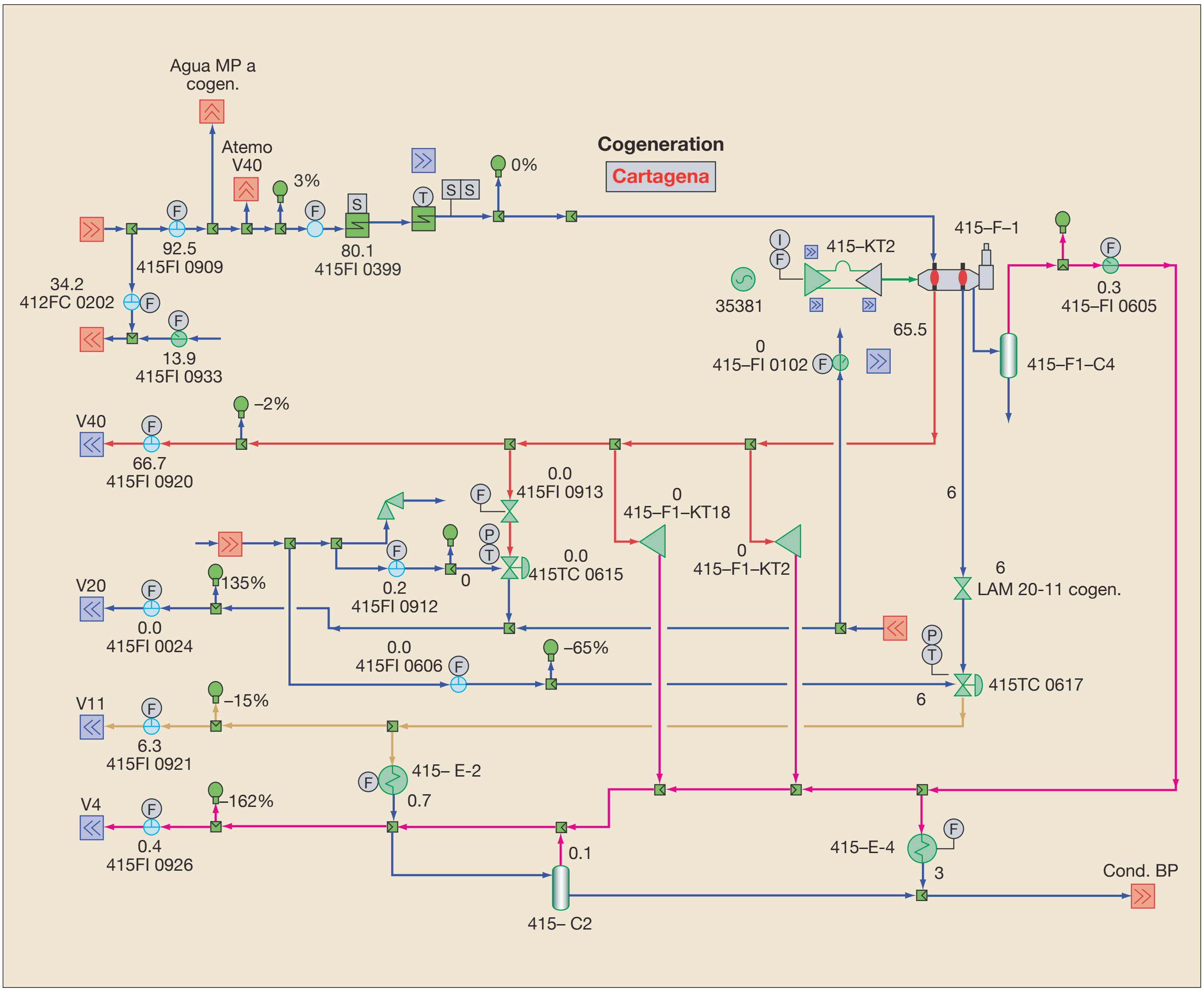

Figure 2 Cogeneration plant view

operators can navigate through the model and inspect the details of each piece of equipment, sensor, header or line.

Project stages

The main stages of the project are:

- Data collection and control system review
- Software installation
- Model building and configuration for optimisation
- Midpoint review and user training
- Burn-in period.

Data collection consists basically of preparing system diagrams, real-time database tags and equipment information, as well as price-related information.

The control system review's main goals are to develop a good understanding of how Visual MESA's optimisation handles and process constraints are related throughout the site control system, and to identify any new control strategies or changes to existing strategies that are needed to implement the optimisation. This is to ensure that suggestions for optimisation can be properly implemented using the site's operating procedures, control strategies and control structure.

Software installation is carried out on a server accessing the real-time database (plant information system) via a standard OPC DA/HDA interface. Software installation on PC clients is also carried out to enable client-server access to the model and to work with the model in standalone mode.

Model building and optimisation configuration involves a detailed model of steam, fuels, electricity, boiler feed water and condensate systems, including all of the interactions between these systems, real plant constraints and degrees of freedom of operation.

Figure 2 shows a representation of the cogeneration plant. Such a model is scheduled to perform automatic executions of the optimisation of the entire system and is continually populated with validated live plant data. In this implementation, the main optimisation handles of the energy system are:

- Fuels to fired boilers, such as fuel oil and fuel gas
- Reposition fuel-to-fuel gas network, such as LPG and natural gas
- Fuel gas flaring
- Fuels to post-combustion (after-burning) at the cogeneration unit
- Steam generation at fired boilers
- Steam letdown
- Steam vents
- Steam turbo-generator management and corresponding electricity generation

- Heat recovery steam generator in the cogeneration unit
- Gas turbine load in cogeneration and corresponding electricity generation
- Steam injection to the gas turbine
- Pump swaps (steam turbine and electrical motor drives options).

The main constraints are:
- Process energy demand
- Burner capacity
- Emissions limits
- Contractual constraints, such as natural gas and electricity supply contracts.

Recommendations given by the model can be taken into account by operations on a daily basis. The model used for online, real-time optimisation is also used in standalone mode, populated with either current or historical data, to perform case studies for planning or to evaluate alternatives for better operation of the energy system.

Midpoint review is carried out to review the model and optimisation with the users. At the same time, user training takes place.

The burn-in period corresponds to a fine-tuning of the model, operating report and optimisation based on operations feedback in order to achieve day-to-day use of the application. Operators usually receive a set of recommendations by means of a custom report. A shift supervisor is indicated as the person in charge of coordinating changes each day.

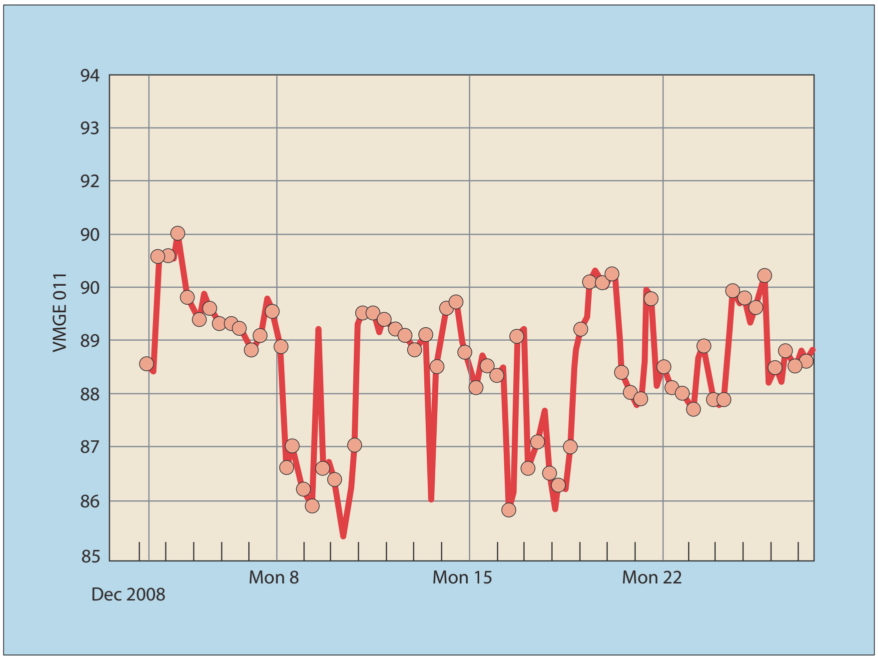

Figure 3 Boiler efficiency trend

Results

As a result of the project, information about the refinery's energy system is organised into a single model and a single environment, to which everyone has access. A calculation of equipment efficiencies is carried out as part of the model's performance-monitoring activity. Figure 3 shows the trend of calculated efficiency for one of the boilers.

This is important not only to indentify early issues that eventually need maintenance or the involvement of operations, but also for optimisation and better load balance in the boilers.

Other monitoring aspects include the continuous auditing of the energy system so that data can be relied upon for evaluating the value of energy production and usage, and hence waste can be eliminated. Imbalances are flagged graphically by using balloons of different colours and sizes (see Figure 4). This is important for checking instrumentation and to evaluate the need for new measurements.

Frequent and large-scale changes in fuel and electricity prices have made the use of an online model for day-to-day operations particularly important.

Some of the operational changes require adequate planning. For such cases, the model can be used in standalone mode. For example, during the day, the operator in charge runs the model with an electricity price forecast for the next day and decides if it is necessary to consider operating the cogeneration unit at a predefined load (instead of at base load) during the night. Market electricity price forecasts are available for each day. During the night, electricity prices usually fall and it is on this basis that the opportunity to operate cogeneration at a predefined load can be evaluated.

For the first eight hours of the day (that is, from midnight to 8am) the optimum operating conditions for the site's energy systems are calculated, taking into account the different conditions forecast for each hour. Main changes correspond to the electricity price, represented in Figure 5 in terms of delta with respect to current price. Delta with respect to base load recommended by Visual MESA is also plotted, along with

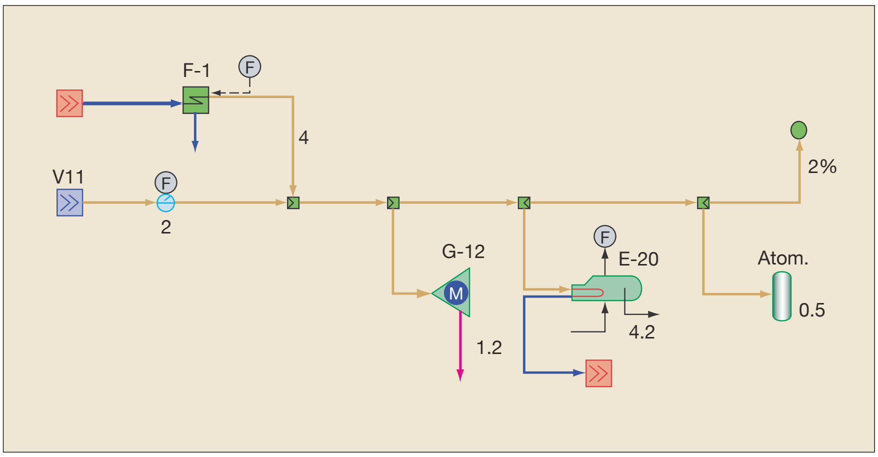

Figure 4 Representation of imbalances

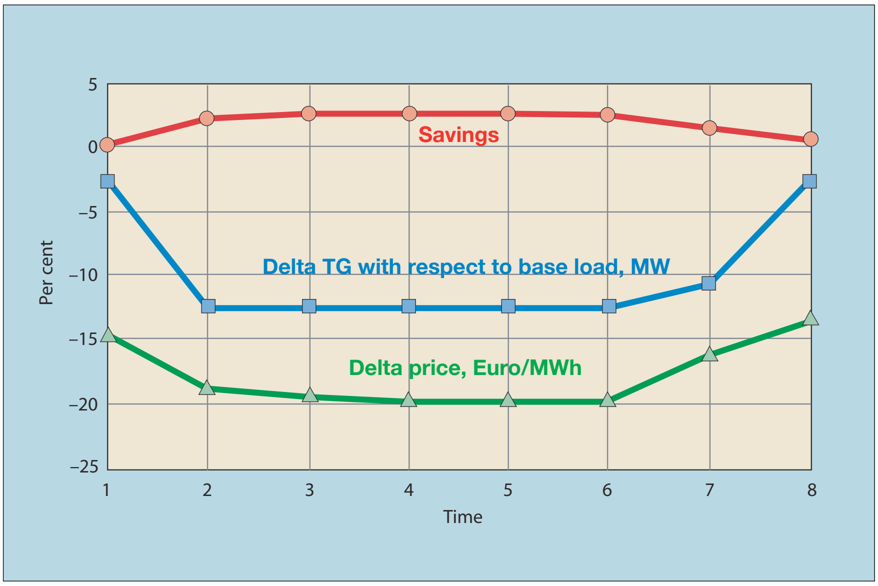

Figure 5 What-if planning study for cogeneration based on electricity price changes

savings, with respect to total energy costs that can be obtained under the recommended operating conditions.

In this example, the recommendation is to work at a predefined load throughout the night. Sometimes, the incentive to do this might apply for only one hour during the night. In such cases, the change should not be applied because it could be impractical from an operational point of view, based on the time needed to stabilise the process after each change.

Such a planning study can be performed with the Visual MESA Excel Add-in. Data for different scenarios can be loaded into an Excel spreadsheet. These data are sent to Visual MESA, which simulates the cases and outputs the results to the same spreadsheet.

Figure 6 shows another example for a similar study: a parametric analysis of optimum electricity production against electricity price. For higher electricity prices, the suggestion is to maintain cogeneration at base load — the lower the price, the lower the savings (since the income from electrical power export is lower).

For prices lower than a certain value, it is not convenient to continue exporting electricity. In which case, Visual MESA's recommendation is to reduce electricity production from cogeneration by shifting to part-load operation.

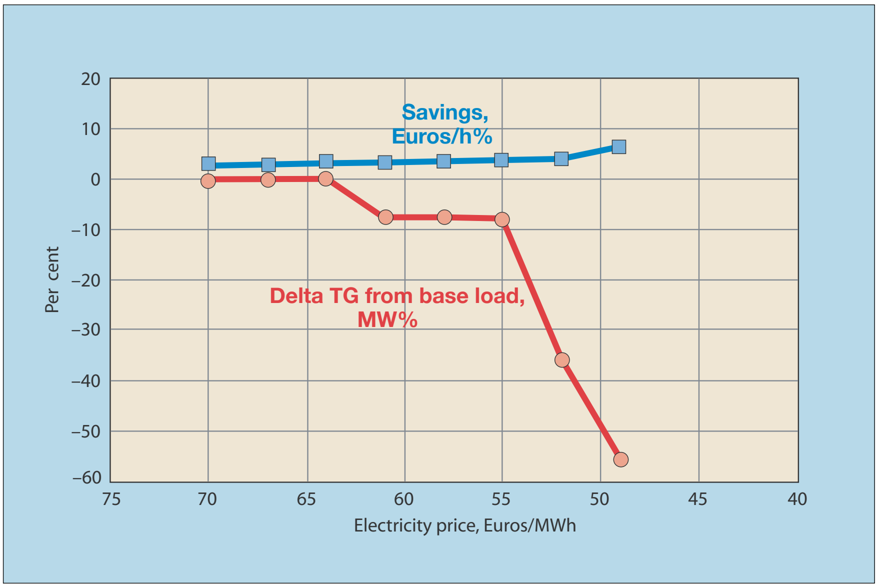

Figure 6 Change in electricity production vs electricity price

Conclusions

The project has provided full understanding of decision variables and associated constraints, which are sometimes hidden or ignored. Additionally, centralisation of responsibility for optimal operation of the energy system has been achieved.

A proactive support programme is under way, with the aim of ensuring that the benefits of the project are sustained and that the health of the model is maintained over time.

The authors would like to thank the process department at Repsol Cartagena refinery for their detailed review of this article.

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