Optimization of the combustion process at Vattenfall Värme, Uppsala district heating plant in Sweden

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Summary

A process optimization system was implemented by applying the MultiSimplex software in the combustion process at the Uppsala district heating plant in Uppsala, Sweden. This project was carried out during 1998 - 2002 and was funded by the plant owners. To date, the optimization project has yielded two important results: 1 Automation of the combustion process. 2 Substantial emission reductions, 30% lower NOx emissions, when the combustion process is controlled by MultiSimplex in automation mode.

End-user area		Target Audience		Technical	
	New buildings		Citizens		Energy efficiency
	Refurbishment of buildings		Households		Heating
	Transport and mobility		Property owners		Cooling
	Financial instruments		Schools and universities		Appliances
■	Industry		Decision makers		Lighting
	Legal initiatives (municipal regulations, directives, etc)		Local and regional authorities		CHP
	Planning issues		Transport companies	■	District Heating
	Sustainable communities		Utilities		Solar energy
	User behaviour	■	ESCOs	■	Biomass
	Education		Architects and engineers		Wind
	Other		Financial institutions		Geothermal
			Other		Hydro power
					Other

Context

Nitrogen oxides acidify lands and lakes, carbon oxides impact on global warming. An optimization of a combustion process will decrease the emission of nitrogen oxides and carbon oxides and will also save hundreds of thousands of Euros in pollution taxes every year. In a world of ever increasing environmental demands and international competition there is a constant pressure on energy suppliers and manufacturers to become more efficient. It has been especially important for industries with harmful emissions to improve their operations since they face both competitors and tougher environmental demands. In Sweden, the pollution taxes on NOx are 4 500 Euro per yearly tonne emitted and there is a new limitation on CO emissions that will take affect starting 2005. Plants, which are non-compliant, run the risk of having their plants closed down or facing lawsuits. The combustion process is of particular interest for quick practical implementation of continuous improvement methods for mainly two reasons: It will see much tougher emission requirements in a few years. It also uses raw material that requires continuous changes of the control parameter set points in order to always strive towards optimal operating conditions.

The main objective with the project was to decrease the NOx emission as well as the NH_3 consumption in the combustion- and flue gas cleaning process.
Optimization of individual machines and instruments is an increasingly less efficient activity. With the current demand on efficiency, an optimization of the whole process is required. MultiSimplex® is an efficient tool for optimization of whole processes.

Objectives

The main objective was to improve the environmental standards of the combustion process at the Vattenfall värme, Uppsala district heating plant. This objective was to be carried out by establishing a combined output parameter (called a joint response) and then optimize the joint response. The joint response was composed by NOx-emission, and NH_3-consumption. The objective was also to automate the operation of the combustion- and flue gas cleaning process. These objectives were to be carried out without limiting or disturbing the production.

Process

The MultiSimplex® technology can be referred to as an evolutionary operation (EVOP). EVOP was introduced in the 1950s. The basic idea is to replace the static operation of a process by a continuous and systematic scheme of perturbations in the control variables. The result is evaluated and the process is shifted in the direction of improvement. The simplex method was originally developed for evolutionary operation, and is very suitable for this purpose. The simplex method is especially appropriate when:

- Process performance is changing over time;
- More than three control variables are to be perturbed;
- The process requires a fresh optimization with each new lot of material.

In most practical optimization situations more than one response variable must be considered simultaneously. MultiSimplex® uses the approach of fuzzy set theory to form a realistic description of the optimization objectives. Different response variables, with separate optimization objectives, can then be combined into a joint response.
In an ideal world, the optimum levels for a process would be easy to find. But in all reality, the world is complex, nonlinear and multivariate. MultiSimplex® is a multivariate nonlinear optimization tool. It seeks the optimum step-by-step. Ordinary statistical methods require the fulfillment of many assumptions concerning distribution, linearity, etc. The MultiSimplex® methods do not have to be adjusted to such assumptions, and are consequently easier to apply to most real world problems.
The MultiSimplex optimization tool interacts with the control system and continuously changes process parameter set points in order to always strive towards the continuously changing optimal operating conditions, yielding the wanted process output.
The tool can be integrated with any modern control system.
New control parameters can also be added to the system when further process optimization is wanted, or, as the plant is being upgraded or modified.

In this project the emission of NOx and NH_3 consumption were to be minimized by the optimization tool. The combustion processes, with changing raw material and tougher environmental restrictions makes a good case for practical implementation of continuous process optimization. In this very application the input parameters NH3 injection flows and flue gas reflux have been connected to MultiSimplex in order to continuously find the best set points for these parameters, which minimizes the emission of NOx and consumption of NH3.
The very use of the MultiSimplex tool also drives plant operators to consider issues such as improvement of measurements; other control system applications and also connections between process systems, helping to improve the overall plant operation.

Financial resources and partners

The project cost was approximately 100 K Euro and was fully funded by the plant owners.

Results

Saving energy was not the objective of the project and only automation and emission reduction issues were considered.
The plant emission cost is based on EURO/ton NOx emitted and liters of NH3 consumed. The installation of the MultiSimplex® system has resulted in a 30% lowering of the NOx emissions with unchanged NH3 consumption. Since the first year of the installation (1998) costs for NOx pollution taxes were decreased by 200,000 EURO, annually. Hence, the economical benefits were considerable and the project was paid off in less than one year. If the savings from the automation of the process had been considered, the total savings probably would have turned out to be greater.
The environmental benefits were substantial with a reduction of 30% of the NOx emissions.
The work required for implementation of this particular application of the software tool can be translated into 0.5 “man-years” /application.
The implementation and utilization of the tool changes the plant operation in several ways. It drives a systemized handling of all available control and output signals. This simplifies the process of adding new control signals to be included in the optimization routine. It also simplifies the maintenance of the signals and the sources of those signals (motors, sensors, etc). The utilization of the tool also highlights important relationships and enhances understanding of the plant itself. The automation of the plant results in freed resources for “higher level” work, for example, experimentation and considerations regarding possible introduction of new measurement. Another field that was explored was possible connections between process systems.
The energy savings were not evaluated. However, a lower emission is a good indication of more efficient fuel usage. The Energy in this particular plant is produced from incinerating domestic waste “fuel”.

Lessons learned and repeatability

We learnt that the “joint response” concept is a powerful method of simultaneous optimization of several outputs at the same time and that the very construction of a joint response alone, for an application like this, results in new insights about what you really want to optimize.
We learnt that it is economically, environmentally and organizationally beneficial, to automate the operation of a combustion process. The reasons for this are lowered emissions and pollution taxes as well as the creation of more intellectually challenging work tasks for the personnel involved.

Long-term success of introduction of new methods is a function of the new methods themselves and the acceptance of them from those whose work will be affected by the new methods. To ensure the long-term success it is important that representatives from all groups that will be affected by the implementation are participating in the project from the beginning. We learnt how important it is to have buy-in from the plant personnel, on all levels.

We learnt that the more different software components you use in an application, the more interface problems you will encounter. Hence we have now developed an application with fewer components, which can perform the same task as the multi component application used in this case. This will lower the implementation time significantly and decrease the training needed for the plant personnel enabling them to completely handle the system themselves.

The project has been "replicated" on the biomass fuel heating plant at the Stora Enso Fine Paper, Nymölla mill (Sweden). Here the objective was to reduce both NOx- and CO-emissions. Secondary- and tertiary- air flows were connected to MultiSimplex in order to continuously find the best set points for these parameters, which minimizes the emission of NOx- and CO- emissions. The result was a 10% reduction of both NOx and CO- emissions.

This indicates that the project could be repeated in any combustion process using waste or biomass as fuel, anywhere in Europe.

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Printed reports or other literature available:
Title: MultiSimplex 2.1.3. (Demo software downloadable at www.grabitech.com)
Sharpen your competitive edge (brochure available at www.grabitech.com)
Your process can do even better (brochure available at www.grabitech.com)
Matematik minskar utsläppen (reprint from energimagasinet available at www.grabitech.com)

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