Modern Automation Concepts improve the Profitability of Power Plants

Concepts and experiences from three plants, including use of the prevalent U.S. start-up mode

Ruud Wienk, Nuon Power Generation bv, The Netherlands

Bernhard Meerbeck, Siemens AG, Power Generation, Germany

Introduction

Maximum profitability is the focus of interest for all power plant operators over the entire life cycle of a plant. As a result, it is necessary to constantly assess the potential of improvement measures. The decisive factor here is not so much the technical feasibility, but rather the profitability of such measures. As the implementation of instrumentation and control (I&C) measures such as optimization of the start-up process or enhancement of plant flexibility entails a minor investment only in software, payback times can be very short.

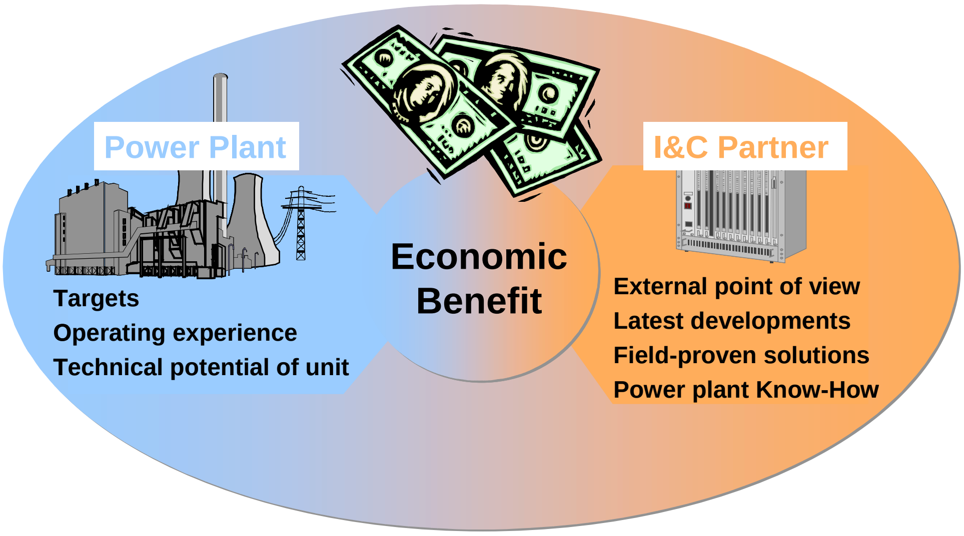
This paper first describes how to detect profitability potentials in existing or new plants. Two examples from plants with special I&C functionality from Siemens demonstrate the tangible benefits of I&C improvements. Finally, the project Velsen 24 exemplifies from the customer's point of view the ambitious approach of a comprehensive I&C modernization.

Detecting profitability potentials

Combining the different perspectives of power plant and I&C partner is the key for a successful implementation of improvements by I&C, see Figure 1.

On the power plant side, this especially means the definition of the targets and conditions for future operation of the plant. When the technical potential for improvements is scrutinized, the power plant also contributes the operating experience including the technical limitations of the plant. On the other hand, the I&C partner provides an external and neutral assessment of plant operation based on experience from other plants and knowledge of the latest developments in process optimization. Seen against this background, it becomes obvious that process know-how on the I&C side is absolutely indispensable.

Figure 1: Cooperation between power plant and I&C partner



After the targets are defined, a number of aspects for improving the profitability of the plant are checked. Depending on the plant and its operational conditions, various solutions from the examples given in Figure 2 can be profitable.

Lower fuel costs, e.g. through increased HP temperatures,

Reduced losses, e.g. by optimized start-up or

Higher returns, e.g. by participation in frequency control.

To estimate the economic potential of the measures during this phase, special benefit calculation tools have been developed /1/.

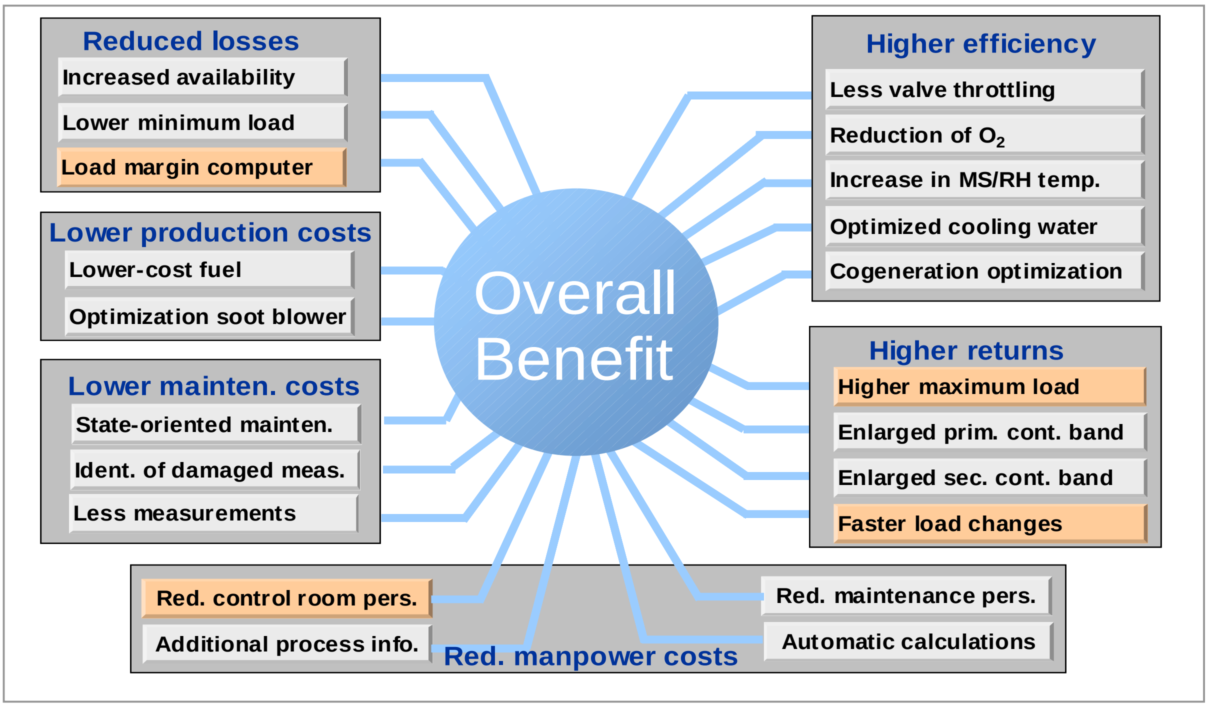


Figure 2: Examples for benefits from I&C modernization

Example 1: Increased maximum load in Callide, Australia

Station C of CS Energy in Callide

Founded in 1997, CS Energy is the largest power supplier in Queensland, Australia and operates power plants at three different locations. During 2000/2001, Station C (2 x 420 MW, hard-coal-fired) was added to the Callide site.

The I&C solution

As power in Australia is scarce in the summer time, Station C needed the capability to maximize electrical power output during periods of high load demand. For this purpose, the module “Increased Maximum Load” was implemented. It coordinates the controlled deactivation of HP feedwater heaters. This makes it possible to run the plant at nominal steam flow with up to 110% rated load for a slight reduction in efficiency.

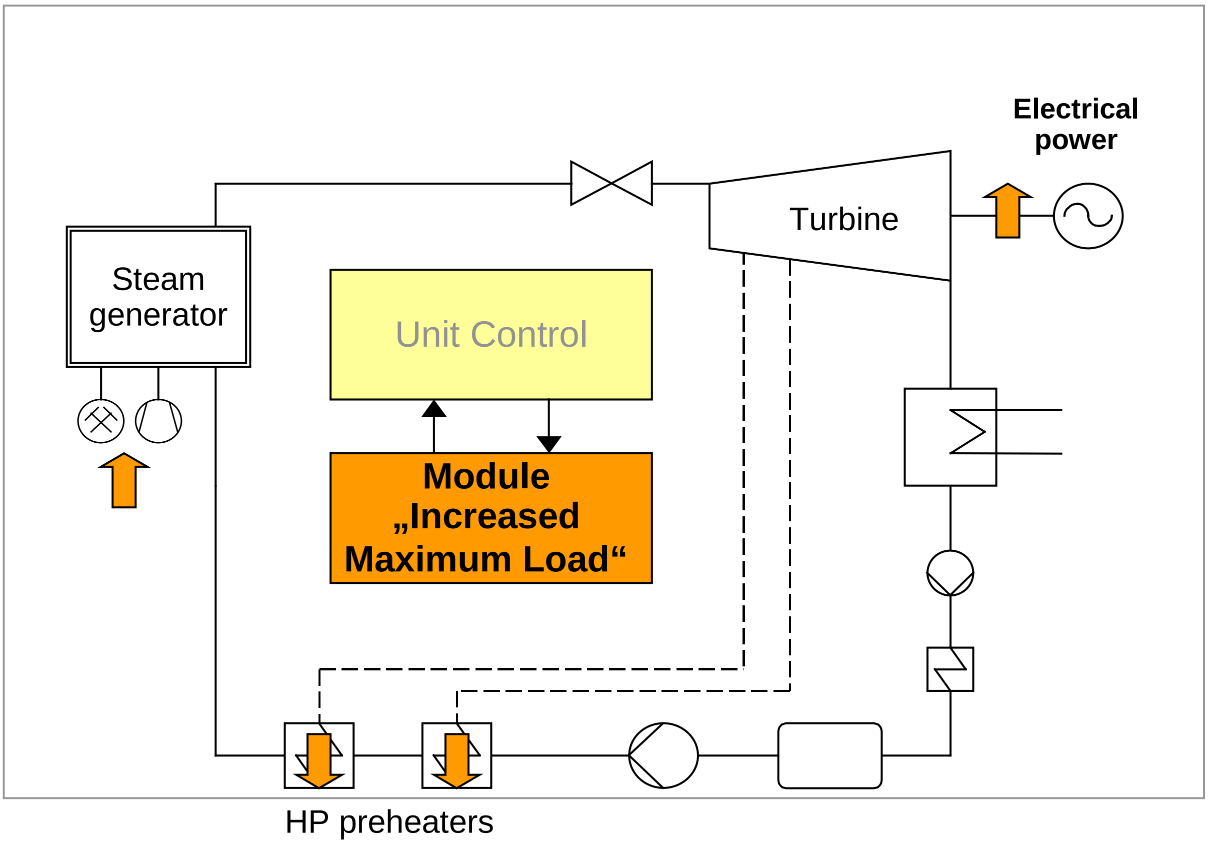


Figure 3: Integration of Module “Increased Maximum Load” into Unit Control

As shown in Figure 3, the module is seamlessly integrated in the unit control. In the overload mode, the dynamic model of the plant incorporated in the unit control is used to adjust the regular dynamic and steady-state setpoint for the steam generator in such a way that the HP feedwater preheaters are deactivated without any impact on the electrical power.

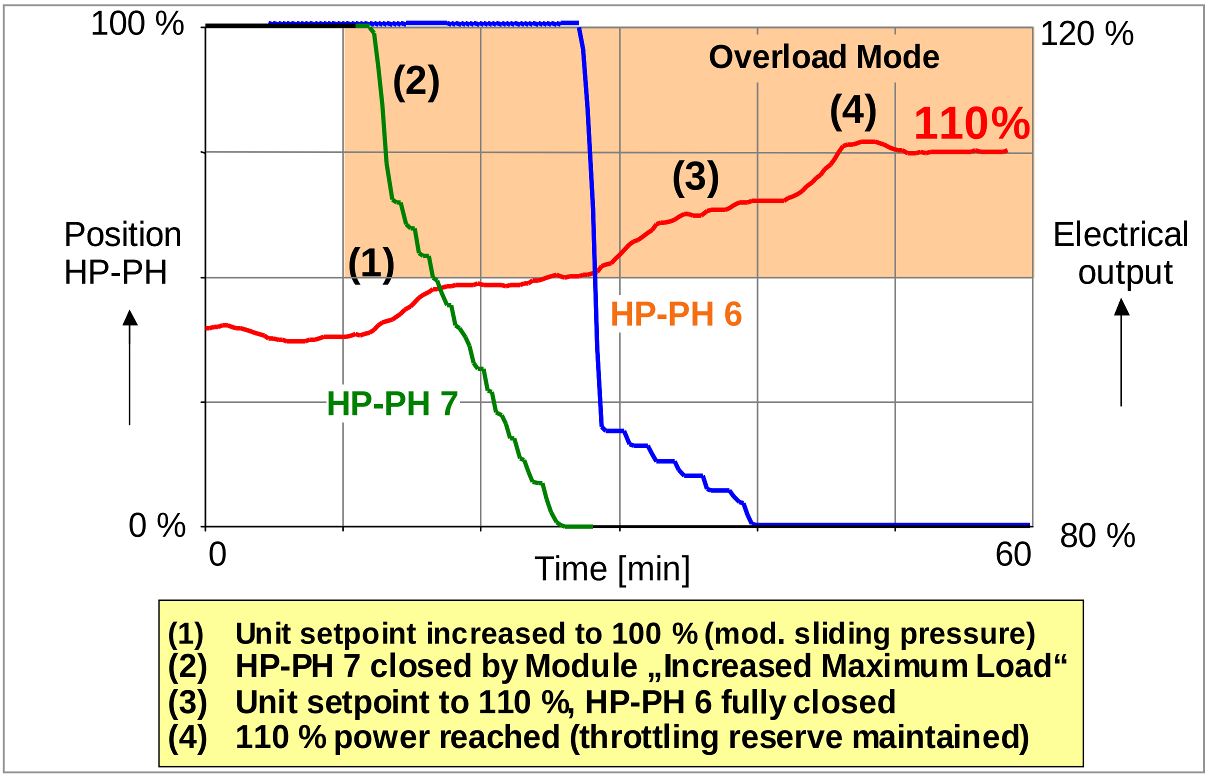


Figure 4: Increasing the load to 110%

The actual process of increasing the load to 110% can be seen in Figure 4. When the load setpoint is increased to 100% (1), automatic smooth shutdown of HP feedwater preheater 7 is started (2). This process is spread over about ten minutes to minimize the thermal stress on this feedwater heater and on the economizer. The amount of fuel needed to compensate for shutdown of HP feedwater preheater 7 is added to the steam generator load in parallel to the regular load increase to 100%. As a consequence, the electrical output changes in the same way as under normal load control. The procedure is similar on shutdown of HP feedwater preheater 6 (3). After shutdown of feedwater preheater 6 is completed, the plant is operated in steady-state at 110% load (4). When the load setpoint is reduced from 110%, the HP feedwater preheaters are activated again in the reverse order.
For the operator and load dispatcher, the only difference from normal operation is that the plant can now be operated up to 110% nominal load instead of 100%.

The Benefit

The economic benefit of the module “Increased maximum load” is tremendous. During the four summer months the plant is operated from 7 a.m. to 7 p.m. in the overload mode. During this period, the price paid for electricity is about twice the normal price. Compared to this, the slightly higher fuel costs are negligible.

Example 2: U.S.-style start-up

For plants operated as intermediate-load or peaking plants, 50 to 100 start-ups per year are common. In such cases, optimized start-ups can yield huge benefits.

Current solution in Europe

The standard procedure for power plant start-up in Europe is to open the HP bypass station immediately after boiler lightoff, with a minimum position guaranteeing a minimum steam flow. Subsequently, steam pressure and temperature are raised to the turbine rolloff parameters. At the time of turbine rolloff it is common to have five times more steam produced in the boiler than is required by the turbine. That means that 80% of the steam produced in the boiler is dumped to the condenser. Steam pressure and temperature in the boiler are also much higher than needed at the turbine inlet at this stage, resulting in significant throttling of the turbine valves to reduce these parameters to the required levels.

Solution in the U.S.

In the U.S., by contrast, plant start-up is performed with the HP bypass station closed or even without any HP bypass station. As a result, all the steam generated is retained in the boiler until adequate pressure and temperature levels have been reached to allow admission of steam to the turbine.

New Solution

Combining the advantages of the US-style start-up and the methods to optimize start-ups in Europe, SIEMENS has developed the "Loss-free quickstart" module. Its main features are:

- The fuel flow is increased when the steam pressures and temperatures indicate that there is no longer any water in the superheater section.
- Using the well-known predictive load margin computer, steam production, pressure and temperature are increased in a manner that ensures that admissible thermal stress levels are not exceeded for critical boiler components.
- Warming-up of the turbine is started here at low steam pressure and temperature levels in the boiler. The same applies for synchronization of the turbine-generator.
- Drains are used to influence steam pressure and flow, especially to prevent flow imbalances and instabilities that can occur on low flow.

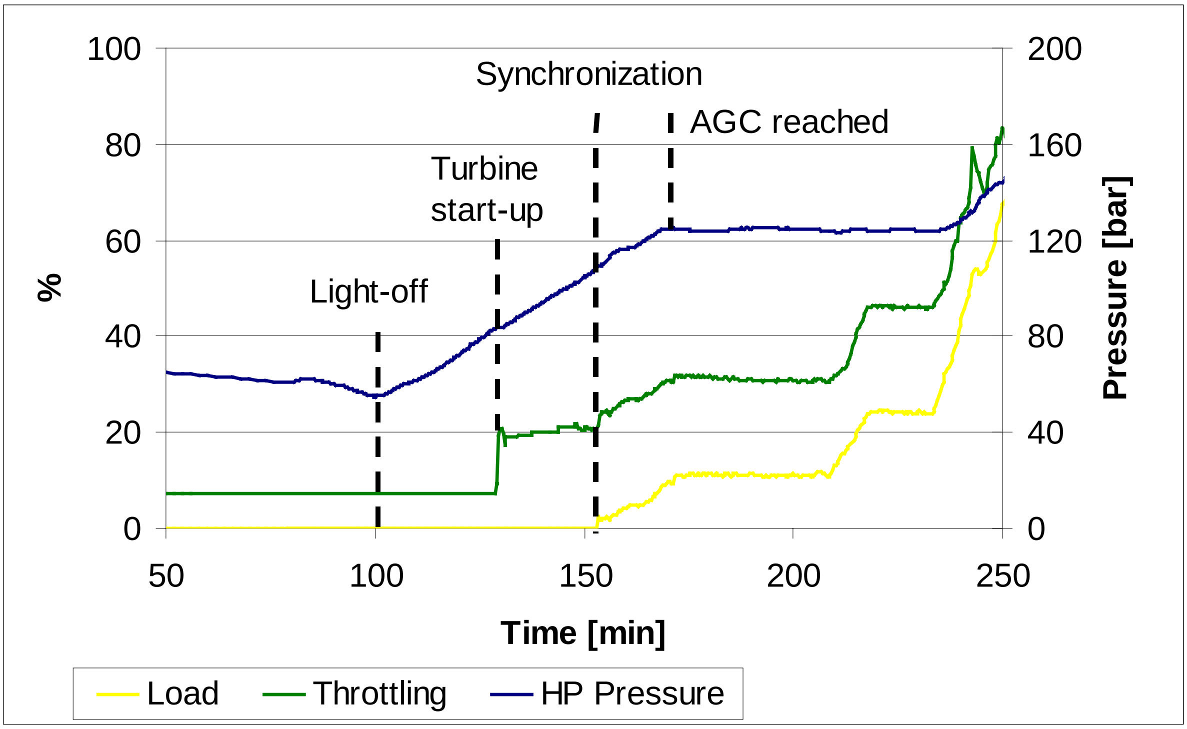


Figure 5: Start-up of an 215 MW drum-type plant without HP bypass

A warm start for a gas-fired drum-type boiler rated at 215 MW is shown in Figure 5. Pressure is increased in an almost linear function from lightoff up to the minimum pressure of 120 bar. Some 25 minutes after lightoff the turbine is rolled off, 28 minutes later the turbine-generator is synchronized and a further 17 minutes later the minimum load of 10% is reached.

Application to other plants

As explained for a drum-type boiler, the "U.S." start-up module also has been applied to once-through boilers in the U.S. As there are no major differences between power plants in the U.S. and Europe, it is also possible to employ the module in European power plants. **Depending on the level of automation, savings of between 30% and 50% in start-up costs are realistic. As this reduction can be realized solely by means of software, very short payback times are common.**

Example 3: Increased plant flexibility in Velsen 24, Netherlands

Nuon

Nuon, one of the largest energy and water companies in the Netherlands, is focused on generation, trading, marketing, sales and distribution of energy, related products and services. Nuon provides almost 5 million private and business customers with electricity, gas and heat, see Figure 6.

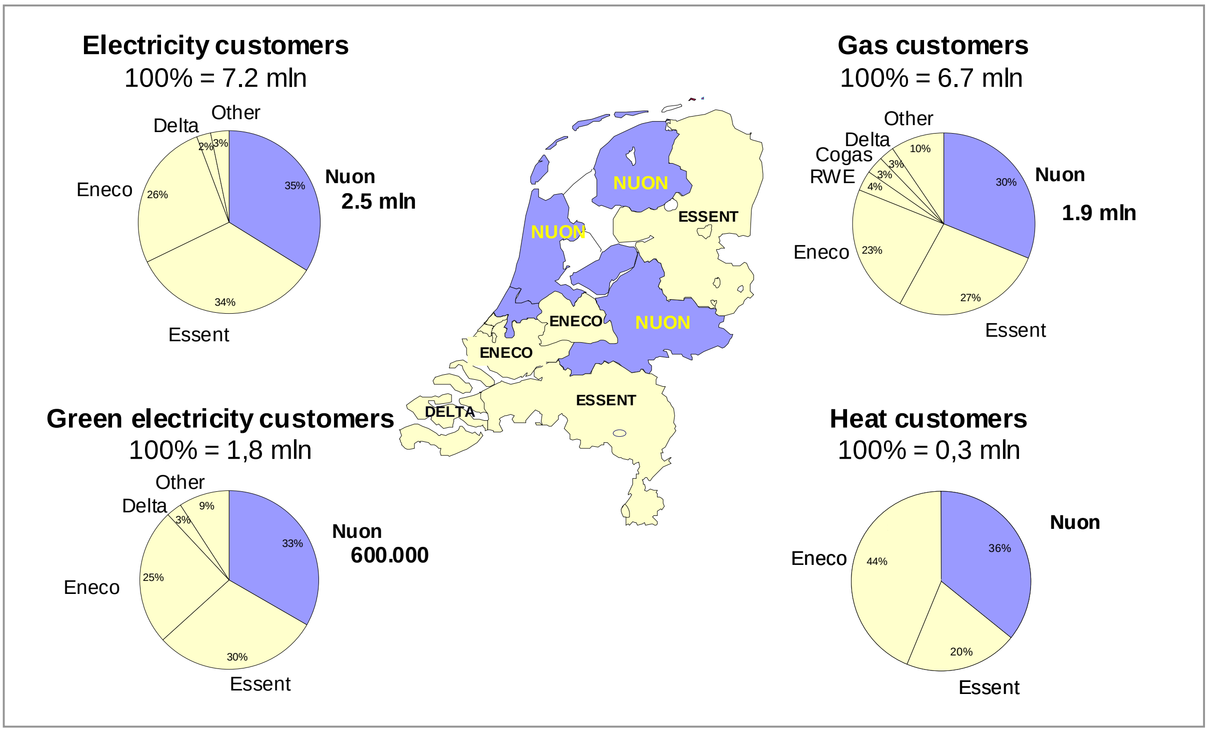


Figure 6: Dutch energy market

(Source: Datamonitor Dutch Utilities survey 2003, Company reports)

Nuon has acquired the power plants of former UNA from Reliant Energy in December 2003. The plants are located in Amsterdam (power plant Hemweg and Diemen), Purmerend (district heating with combined cycle), Utrecht (power plant Lage Weide and Merwedekanaal, mainly combined heat and power) and Velsen, see Figure 7.

Nuon owns the Integrated Coal Gasification Combined Cycle (ICGCC) at Buggenum, some smaller heat and power units, wind parks mainly in the Netherlands and Spain and some small hydro power and photovoltaic power units. A new unit “Intergen” in the Rotterdam area will become operational this year and Nuon has contracted the full power load.

The total power production portfolio amounts around 5200 MW electrical power.

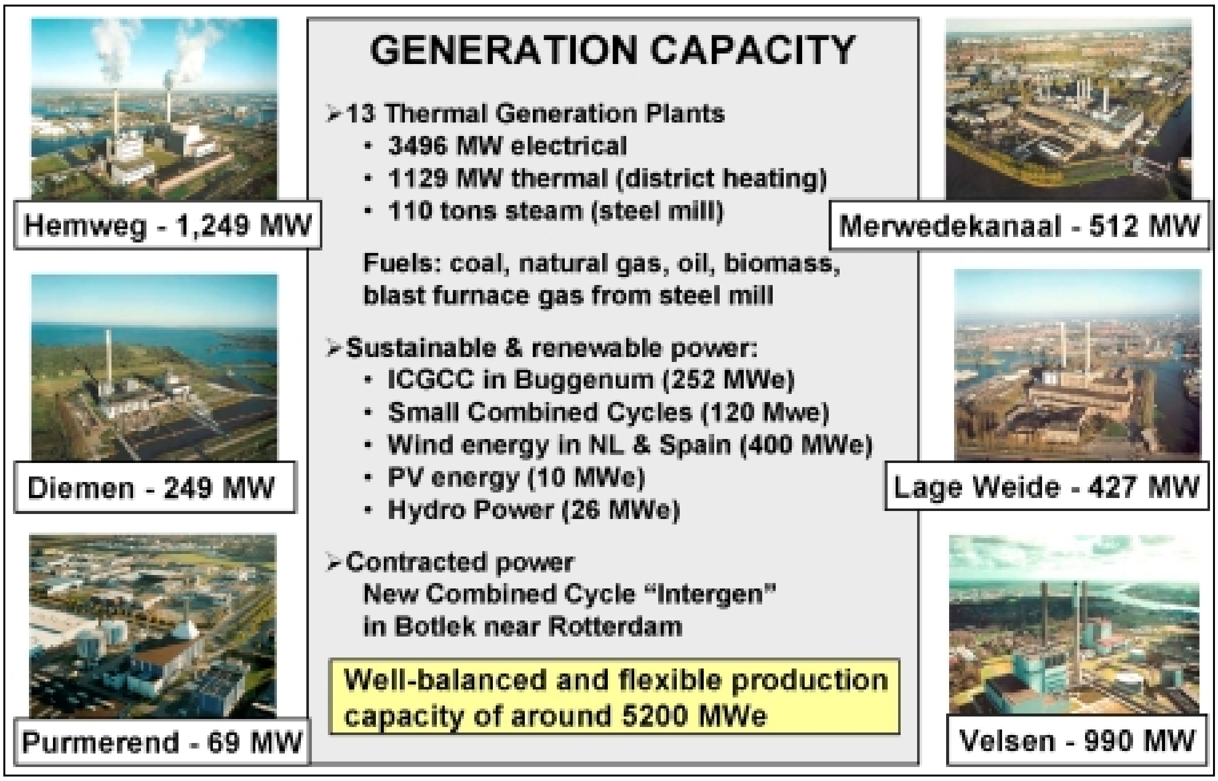


Figure 7: Generation capacity of Nuon

Although originally a Dutch company, Nuon operates internationally through participation in foreign companies, and by building and managing renewable energy projects outside the Netherlands, see Figure 8.

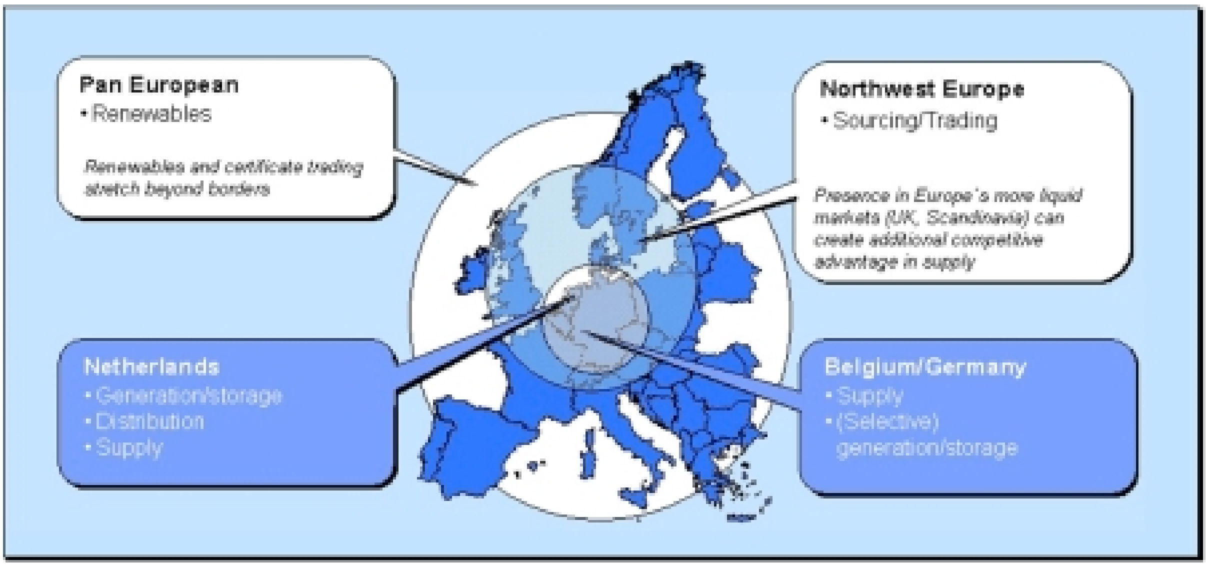


Figure 8: International Operation of Nuon

Cluster Velsen

At the Velsen location north of Amsterdam, Nuon operates the combined-cycle plant IJmond 01 and the two blast-furnace and natural-gas-fired units Velsen 24 and 25.

Unit 24 was commissioned in 1973. It has a forced-recirculation drum-type boiler with 1480 t/h nominal steam flow. Its primary fuel is blast-furnace gas of greatly fluctuating quality from a nearby steel mill, with natural gas used as secondary fuel for load control. The steam is supplied to a 460 MW condensing turbine.

Assessment before modernization

An assessment of Velsen 24 before the project showed that a life time extension of 15 years was economically feasible. During the assessment, the following measures were identified:

Replacement of weldings, heatstressed parts, piping

Standard maintenance according to Long Time Maintenance plan

Removal of hazardous fibers (asbestos)

Replacement of control system and electrical parts

Centralization of control room with VN25, IJmond01 and VN24

The comprehensive I&C solution

The main target of the I&C modernization was to assure continued operation for the next 15 years. In addition, four targets were defined:

Reduction of I&C maintenance costs by decreasing the variety of systems

Operation of IJmond 01 and VN24 from central control room of VN25

Faster start-up and flexible operation with only one operator

Increasing the load gradient from 1.5%/min to 4%/min *a) Reduction of I&C maintenance costs*

The wide range of different I&C equipment in the original configuration is shown in Figure 9. Most of this equipment was obsolete.

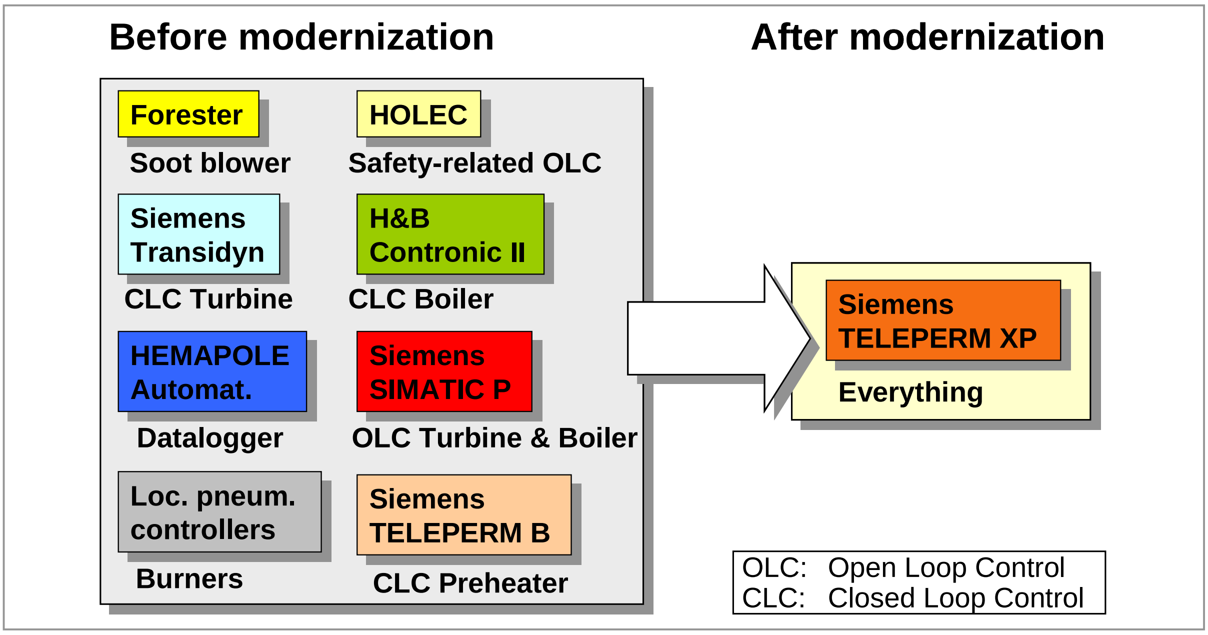


Figure 9: Main I&C systems before and after modernization

b) New Operation and monitoring concept

At the start of the project, Nuon and Siemens defined an Operating & Monitoring concept that allowed the operation of Velsen 24 with only one operator from the control room of Velsen 25. For this purpose, web4txp using standard internet technology was applied, see Figure 10. IJmond01, is also operated via web4txp from the control room of Velsen 25.

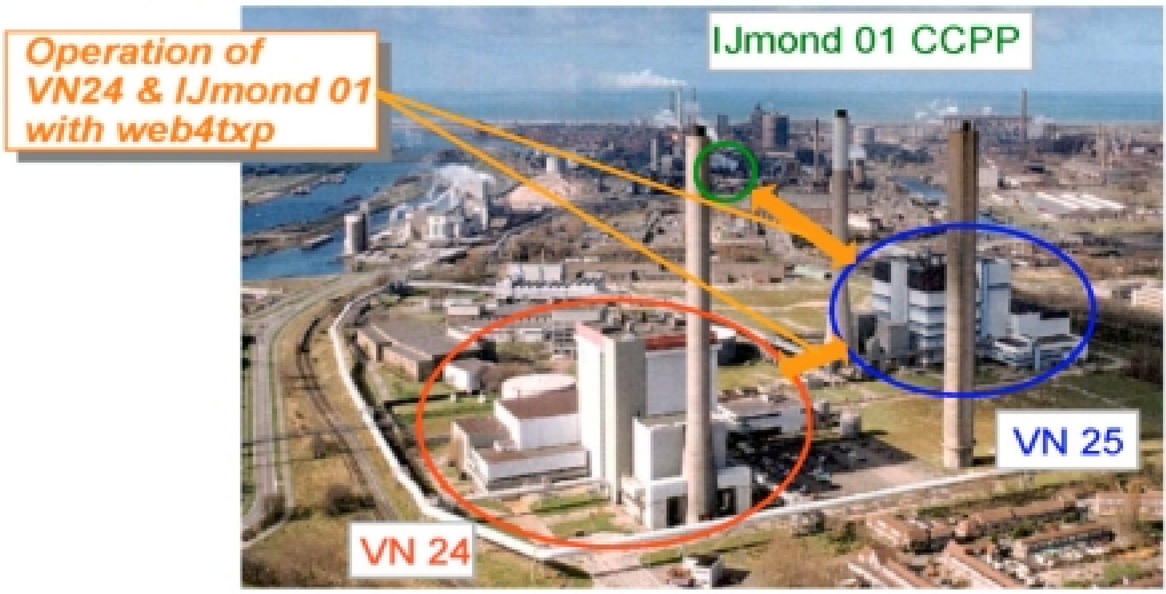


Figure 10: O&M concept for Velsen location

c) Improvement of start-up process

Start-up necessitated a number of manual interventions on the part of the operators, this including the operation of actuators and continuous adjustment of various setpoints according to the boiler condition. As a consequence, the duration of start-ups varied widely. Manually-operated actuators were included in the automation of the start-up process. In Figure 11, the new concept for start-up is depicted. This takes into account the current boiler conditions and the required parameters for rolloff of the turbine. In addition, the allowable temperatures in the furnace and the downcomer are used to calculate the setpoints for fuel flow, steam pressure and temperature. During start-up of the unit, no manual intervention by the operators is now necessary.

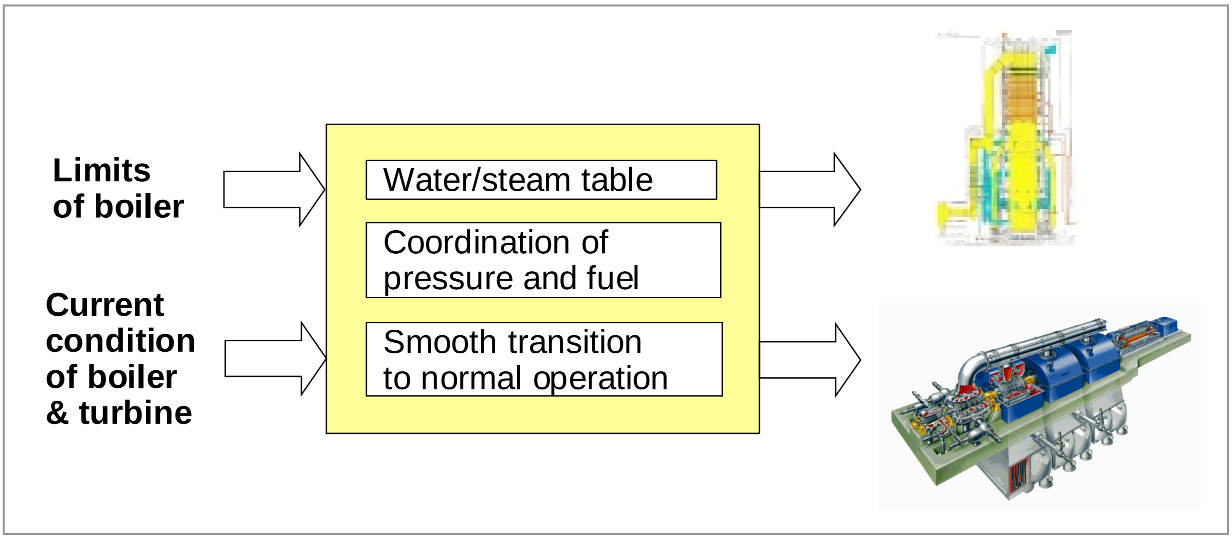


Figure 11: Concept for model-based start-up

d) Improvement of load gradients

In the normal load range, the gradient was limited to 1-1.5%/min by the accuracy of the various closed-loop controllers. The old closed-loop control concepts were closely examined. For critical control loops such as unit control and HP steam temperature control, model-based feed-forward concepts were applied /2/. Details of the unit control are shown in Figure 12.

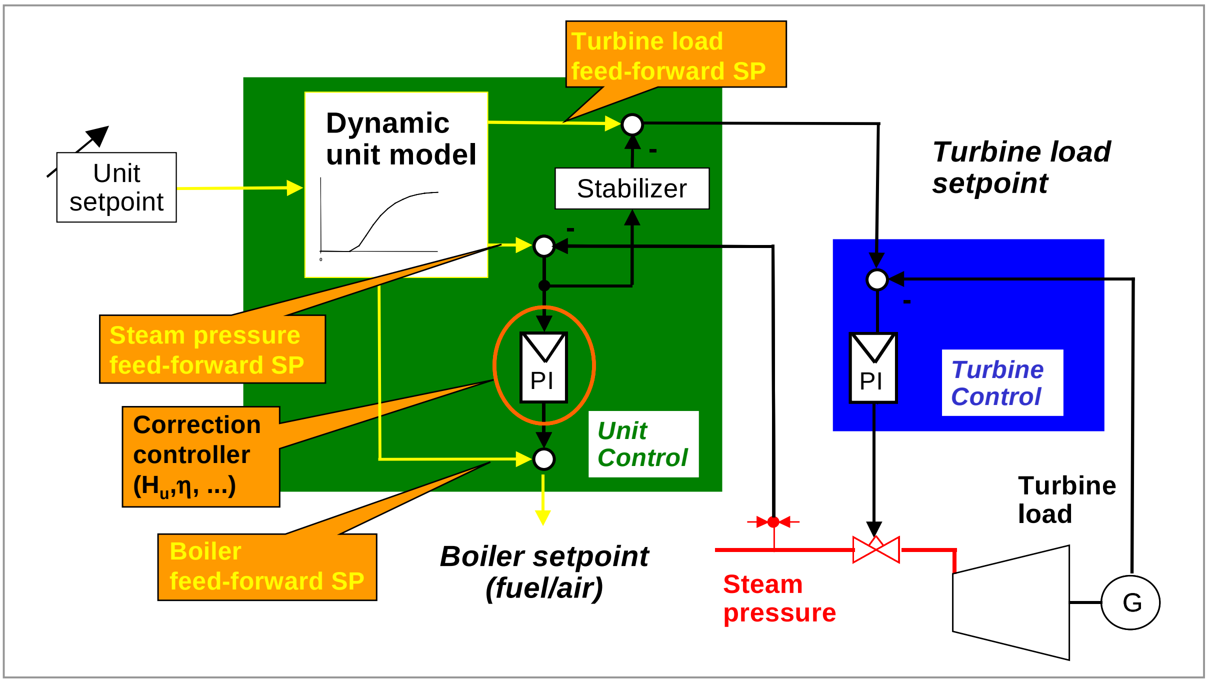


Figure 12: Unit Control of Velsen 24

The unit control coordinates load changes by generating setpoints for boiler and turbine. Under normal conditions, the boiler controls the pressure while the turbine controls the electrical output of the unit. This concept was chosen to prevent the rapid fluctuations in calorific value of the blast-furnace gas from influencing the electrical output.

The setpoints for boiler and turbine are calculated in the dynamic unit model from the unit setpoint as set by the operator or the load dispatcher. If no disturbances occur, no further closed-loop controllers are involved in load changes. If there are disturbances, e.g. a change in the calorific value of the fuel, the pressure correction controller compensates them. The dynamic setpoint for this controller is also generated within the dynamic model. If the deviation for the pressure controller becomes too large, the stabilizer influences the load setpoint for the turbine such that the turbine supports the boiler in maintaining the pressure.

Other critical control loops such as drum level and furnace pressure control were enhanced with the aid of modern I&C system features such as nonlinear filters or parameter adaptation. As a result, load changes can be about three times faster than before I&C modernization.

Two fast load changes with load gradients of up to 4%/min are shown in Figure 13. In spite of the fast load ramps, the steam temperature is almost constant. The steam pressure in that period differs less than 3 bar from its setpoint.

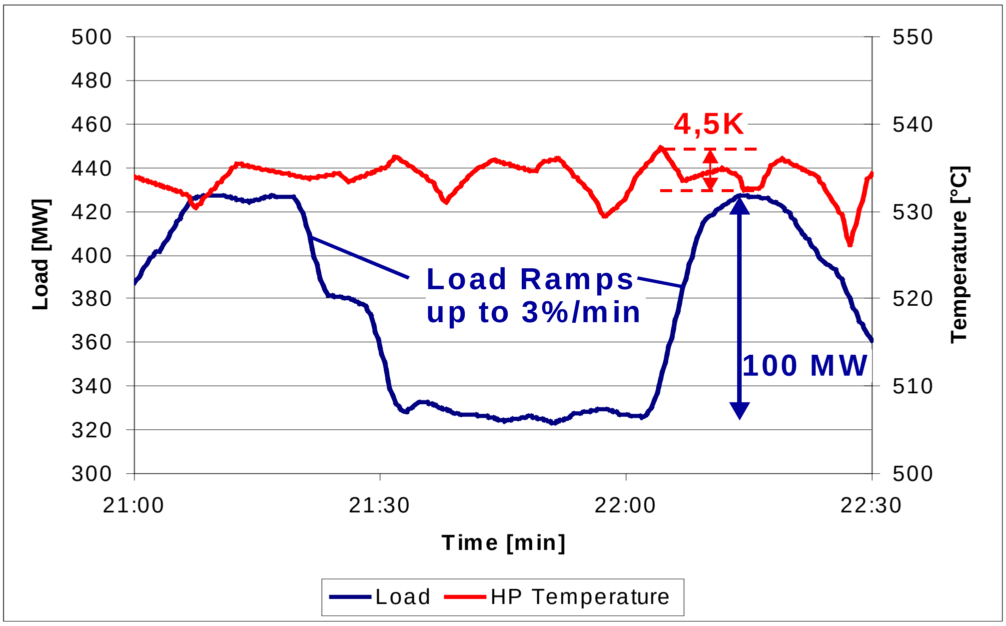


Figure 13: Load changes in Velsen 24

Summary of project

At the end of the project, all the targets defined have been met. **For the next 15 years, Velsen 24 is fit for the ambitious demands of the liberalized energy market.** The close cooperation in the project allowed the unit to be synchronized 13 days after system commissioning started.

Conclusion

The three examples given demonstrate that plant-specific I&C measures are the best way to improve the profitability of a power plant. They underline the importance of solutions tailor-made for the individual plant and process conditions.

References

/1/ Powering profitability, Bernhard Meerbeck, Klaus Wendelberger, Manfred Hüngerle, World Coal, April 2003

/2/ Operational Behavior of a Power Controlled 600 MW Power Plant Unit, Klaus Wendelberger, Reinhold Ackenheil, G.Gleixner, VGB PowerTech 3/2000