Improving Flexibility of the Combined Cycle Power Plant Hamm Uentrop to Cover the Operational Profiles of the Future

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Introduction

The global energy markets are rapidly changing due to increasing renewable power generation and decreasing power prices in the electricity markets in many countries.

This leads to new operating profiles with higher flexibility requirements for many fossil power plants. Combined cycle power plants originally designed for base or intermediate load may require improved start-up performance, extended capabilities for ancillary services, or minimized part loads.

As investment plans for new and flexible power plants are not progressing in line with demand in most European countries, it is of utmost importance to adjust the capabilities of the legacy fleet to future flexibility needs. Flex-Power Services™ is an activity of Siemens Energy Service which targets all aspects of plant operation with an integrated approach (Figure 1).

The investment available for these upgrades and modernizations may be limited due to depressed power prices and their consequences for plant economics. Nevertheless, given close cooperation between plant operator and plant equipment supplier, improved plant performance is often feasible and operational flexibility may be enhanced without excessive changes to components.

This paper presents recent operational enhancements and the ongoing cooperation between Trianel and Siemens to adapt the operational performance of the combined cycle power plant Hamm Uentrop in Germany.

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The Trianel combined cycle power plant Hamm Uentrop, Germany, in a changing market environment

Trianel, a large communal network of 56 shareholders as shown in Figure 2, decided in 2005 to order a combined cycle plant and Siemens was chosen to supply two turnkey single shaft configurations.

Figure 2: The Trianel communal network, February 2014

Both units of the plant Hamm Uentrop had first fire in 2007. Details of the plant, including the gas turbines SGT5-4000F, the steam turbines SST5-3000 and the generators SGen5-2000H are shown in Figure 3 and Figure 4.
Figure 3: Trianel Combined Cycle Power Plant Hamm Uentrop, Germany

Figure 4: Trianel Combined Cycle Power Plant Hamm Uentrop, key data

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The plant was designed for up to 8000 operating hours per year. In 2013 Hamm Uentrop contributed with approximately 4250 full load hours and more than 5200 operating hours per unit to German power generation, despite the challenging market conditions described in Figure 5 and discussed in more detail by Sven Becker in [1].

- Declining price of electricity traded on the power exchange
- Uncontrolled expansion of renewable energy (23.5% in 2012) because of national sponsoring by law (EEG)
  - Rising prices to end customers
- Low CO₂-Price (4,5 €/to CO₂) → increasing CO₂ emissions
  - Increasing power generation of hard coal and lignite
  - Decreasing generation of CCGT
- Slow-pace advancement of power grid expansion can lead to grid instability

Figure 5: Issues and Challenges of the German „Energiewende“

This relatively high number of operating hours was possible thanks to a long-term gas contract at reasonable prices and to the ability to provide the market with ancillary services such as secondary frequency response and minute reserve (tertiary frequency response). In addition to the technical capabilities required for offering flexible operation to the transmission system operator, highly professional energy production planning is a must for the best possible plant economics. The Hamm Uentrop plant is managed by Trianel utilizing specialized software based on stochastic optimization algorithms that helped to improve the profit margin, as can be seen in [2].
Extended requirements for flexible plant operation

The consequences of current market conditions for plant operation are in general:

- **Low profit margin**
- **Frequent part load operation**
  - Reduced efficiency
  - Increased emissions
- **Fluctuating prices on the power trading exchange**
  - Frequent adjustments to the operation schedule (in 15 minute slots)
  - Control of the plant to match grid requirements
- **Increasing number of redispach requests due to instability of the grid**
  - Changes to the operating schedule
  - Delayed start-up times
  - Forced night-time operation
- **Minute reserve and secondary frequency support**
  - High load change requests for short duration (15 minutes) and at short notice

This leads to tougher requirements for operational flexibility in terms of fast transients and frequent part-load operation. The typical generation pattern is no longer dominated by constant load, and continuous operation at maximum power has been replaced by constant trading activity, changing output in 15 minute slots and/or delivering secondary or tertiary frequency response to stabilize the grid. Severe operating patterns as shown in Figure 6 are becoming more and more common in the business.

Declining power prices have made especially the contribution of secondary frequency response more important to plant economics.

In 2011 Trianel requested the original equipment manufacturer Siemens to develop and offer solutions that could help it to stay in the market longer or return earlier!

In combined cycle power plants, the gas turbine plays a major role in the overall performance of the plant, so that Siemens’ immediate response was to accelerate its development activities to steepen the gas turbine load gradient from 13 MW/min to higher values [3,4]. Nevertheless the potential for improving the operational flexibility of a combined cycle plant is very much dependent on integrated solutions that take all components of the plant into account, especially the interaction of the gas turbine with the downstream steam cycle.
Stepwise improvements in the secondary frequency response capabilities of the plant

The request to improve the plant's secondary frequency response capabilities and the subsequent meetings between Trianel and Siemens culminated in a first step: the unit control system was modified to make allowance for a possible contribution by the steam cycle. The prequalification test in April 2013 validated 69 MW in five minutes, an improvement of 9 MW compared to the 60 MW in five minutes which Trianel was used to bringing to the market. Implementation of this “Combined Cycle Load Gradient” was the first time ever in a single-shaft configuration, with the added difficulty that only the sum of gas turbine and steam turbine output can be measured at the generator.

In a second, bigger step, a 26 MW/min gas turbine load gradient was implemented and prequalified in August 2013, totaling a change of 135 MW in 5 minutes, equivalent to an average of 27 MW/min combined cycle net output gradient, see Figure 7. This result was achieved by utilizing the gas turbine and the additional steam turbine power which sets in with a certain time lag within the 5 minutes.
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This successful implementation was based on evolving the gas turbine to achieve higher load gradients and on subsequent investigations targeting the heat recovery steam generator (HRSG). It was found that the mechanical capabilities and the potential lifetime consumption of the faster transients were less critical than expected but the original feedwater control system was not capable of handling the fast load changes and needed to be optimized. Utilizing a feedforward control concept and installing additional thermocouples in the exhaust gas ahead of the first evaporator to permit calculation of the energy balance were the keys to allowing faster load gradients and at the same time reducing temperature excursions (Figure 8).

Within the inlet guide vane (IGV) operating range, the 26 MW/min fast load gradient can be chosen at the control monitor as soon as the plant is fully warmed, which in the case of the gas turbine is about 30 minutes after synchronization. Nevertheless, the time taken to warm up the steam turbine, especially after longer shutdowns of several days, slows down release of the fast load gradient. This proves the importance of integrated plant solutions and sets the next target in optimizing plant performance, as the fast load gradient is especially attractive if it is available as soon as possible after the start of the plant.

Figure 9: Time to release the 26 MW/min fast load gradient after weekend standstills
Tests performed in different steam turbine start-up modes, modified steam temperature control and optimized release criteria for the 26 MW/min fast load gradient showed potential for bringing use of the fast transients forward by more than one hour after a weekend stop of about 56 hours, see Figure 9. The changes and tests were done in close cooperation between Trianel and Siemens. Operating data and observations were submitted by Trianel, innovative start optimizations were proposed by Siemens, and testing in the plant was agreed at short notice by both parties. The improved starts shown in Figure 9 were run in “fast” steam turbine start-up mode, which Trianel did not normally use, as it was penalized by the original equivalent operating hours (EOH) counter of the steam turbine, which counted worst-case design values per start.

A new steam turbine EOH counter was implemented that counts the EOH of a real start/stop cycle, which were found to be a lot lower than the worst-case values, especially if the steam turbine was still at a higher temperature at the onset of start-up. The advantage of the new steam turbine EOH counter for typical weekend and overnight stops can be seen in Figure 10.

Smaller improvements of the release time were gained using modified release criteria. Other improvements are under consideration, utilizing a further optimized temperature control scheme for the steam turbine during start-up to shorten the time between synchronization and release of the 26 MW/min fast load gradient.

Figure 10: Comparison of steam turbine EOH counts with original and new EOH counter for typical starts

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Improving plant flexibility – a constant challenge

Looking forward, further plant optimizations are under discussion. Ongoing cooperation between Trianel and Siemens is looking at all potential areas for improving plant operations.

To improve the speed and efficiency of the start-up process, especially after short overnight stops, releasing faster gas turbine start gradients is under discussion as well as the “Hot Start on the fly” of the steam turbine, a concept that allows highly integrated start-up of the gas and the steam turbines (Figure 11) [5].

Although no decision has yet been taken on implementation of the faster gas turbine start-up gradient, a minor hardware modification (Figure 12) will be made during the next outage. The partners have agreed to make this small extra effort during the next outage rather than to implement it later, as the compressor needs to be lifted for this activity. The availability of the plant is another important key performance indicator in optimizing overall plant performance which led to this decision.

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With respect to availability and with a view to improving plant flexibility, Trianel was open-minded to finding and testing new approaches with the plant designer and equipment supplier Siemens. With availability and the shortest possible outage durations in mind, a fast cooldown process was implemented for the steam turbine and further improved in a first-time application.

**Figure 12:** Modified compressor vane carrier vane ring grooves of Siemens SGT5-4000F

**Figure 13:** Fast cooling may significantly shorten outage durations

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The cooling down curve is shown in Figure 13, representing a fully automated cooldown sequence leading to optimized cooldown curves and at the same time avoiding the need for constant manual adjustments by the plant operators.

The rotor could be stopped after only 2,5 days, allowing access to all shaft components of the single-shaft configuration (gas turbine, generator and steam turbine). A natural cooldown process typically results in a much longer cooldown time of six or more days.

In anticipation of more frequent plant stops with longer durations of several days, further start-up improvements may be a good opportunity. The products Fast Release to Nominal Speed [5] and Degassed Conductivity Measurement [6] may in future reduce cold and warm start-up times.

Further increases of up to 50 MW/min in the gas turbine load gradient in the IGV range may be considered, and also lowering the minimum part load at which the plant can be run [3].

All modernization options will be investigated in depth by Trianel as soon as they may offer benefits considering the expected plant operating profile and the implementation effort is reasonable.

Summary and Conclusions

Changing energy markets, especially in Europe, are leading to new operating profiles with higher flexibility requirements for many fossil power plants. As a consequence, Trianel is adapting the Combined Cycle Power Plant Hamm Uentrop to German market conditions. The technical improvements which have been implemented are already proving beneficial today, but their importance is expected to increase still further, assuming that scenarios for the German "Energiewende" (energy turnaround) as described in [7] become reality in the years to come.

This paper has highlighted specific activities and the ongoing cooperation between Trianel and Siemens. Successful implementation of the 26 MW/min fast load gradient is the most recent example of this fruitful relationship, which is set to continue with further optimizations going forward. Flex-Power Services™ is the activity of Siemens Energy Service which provides integrated plant solutions for meeting enhanced flexibility requirements.

Close cooperation between Trianel and Siemens makes it possible to choose the most appropriate solutions for optimizing the Combined Cycle Power Plant Hamm Uentrop and keeping it in excellent shape to face the market needs of today and the future.
References:


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