Proceedings of ASME Turbo Expo 2011
GT2011
June 6-10, 2011, Vancouver, British Columbia, Canada

GT2011-45458

PREVENTING STANDSTILL CORROSION ON LP TURBINES THROUGH OPTIMIZED SHUTDOWN PROCEDURES

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ABSTRACT

Caused by the deregulated market and the entrance of new power sources, like wind farms, solar power etc. into the market, conventional steam power plants are nowadays operated with frequent start-ups and shutdowns. During lay-up time, general corrosion or even localized pitting corrosion can take place if no preservation measures are applied.

The CECD (Cold End Corrosion Diagnostics) diagnostic method by Alstom enables a cause-and-effect analysis of corrosive attacks - supported by analytical and instrumentation data - and can also be used for determining whether there is a high probability of corrosion in the exhaust-steam area of condensing turbines.

In addition the method allows selective modification of shutdown procedures so that it will be impossible that corrosive attacks occur during short-term downtimes, e.g. during weekend standstills for which normally no special preservation measures are taken.

The paper will give a brief description of the method and mainly focuses on examples already carried-out successfully.

INTRODUCTION

While in the past, thermal power plants in Europe where often continuously running, the experience from Germany shows, that nowadays they are more likely to be operated with frequent start-ups und shutdowns caused by the deregulated market and the entrance of new power sources like wind farms, solar power, etc. into the market. Normally no one is thinking of comprehensive preservation measures during a lay-up time of a couple of days like a weekend outage. Hence general corrosion or even pitting corrosion can easily take place if no preservation measures are applied. Keeping in mind that the availability of a thermal power plant is getting more and more important especially for middle and peak load operation.

Overhauls in the past occasionally revealed cracks in the area of the shaft-side fir-tree fastenings of the blades in large low-pressure turbine for different design solutions and independent from the manufacturer. Metallographic studies showed that the incipient cracks were originally started at places of localized pitting corrosion. It was not possible to figure out a correlation between the number of cracks and the associated number of operating hours or turbine cold starts.

It soon became clear that the localized pitting on low-alloy rotor shafts could not have been caused during normal turbine operation if the steam quality as per OEM specification was ensured. [1]

Instead, it appeared more likely that the shutdown procedures and the conditions during following standstill periods were critical for the occurrence of a liquid electrolyte in the rotor slots.

It is therefore safe to conclude that machines that are frequently taken out of service for a few days (e.g. for weekend standstills) are more at risk than machines that continuously run at base load with hardly any downtimes of this kind.

Based on this experience, the CECD (Cold End Corrosion Diagnostics) method was developed by Alstom.

With CECD, Alstom provides the analytical means and the instrumentation needed to identify the causes that are leading to a high humidity at the condenser neck. This high humidity is likely to be the reason for corrosion attacks occurring at the last stage blades and in the exhaust steam area of condensing turbines. In other words: As long as the relative humidity (r.H.) in the turbine casing is kept at a low level, corrosion is very unlikely to happen.

Using this method, it is possible for Alstom experts to propose selectively modifications of the shutdown procedures to maintain the relative humidity below 40% r.H. so that the risk for components to corrode during short-term outages, e.g. over the weekend when normally no specific preservation measures are taken, can be significantly reduced or even eliminated [2,3].

MEASUREMENT SETUP

The measuring equipment mainly exists of three parts. One is a pyrometer, another one is a humidity probe and the third part is a channel recorder that helps to store and visualize the measured values.

With the help of this instruments the temperature of the turbine shaft as well as the humidity and the temperature in the turbine casing in the exhaust steam area are measured.

To visualize and record the measured signals, the transmitters of the measuring devices are connected to a channel recorder. This recorder enables to proceed the measurement during the whole lay-up period.

The basic measuring arrangement is shown in Figure 1.

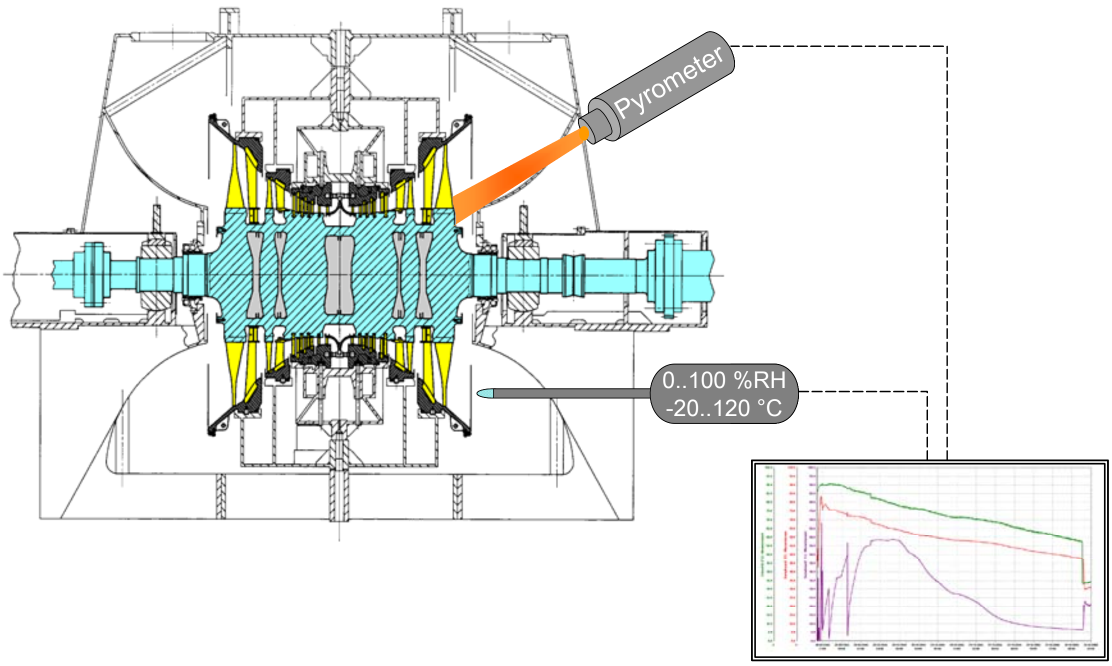

Figure 1: Rough setup of the CECD measuring device

EXEMPLARY EXPERIENCES FROM DIFFERENT POWER PLANTS

In this chapter, exemplary experiences from former measurement series at different power plants will be described.

The first step of each CECD measurement series, after the installation and commissioning of the measuring equipment, is an initial measurement of the present state. That usually means, a shutdown procedure according to the specific power plant instructions is accompanied and recorded.

POWER PLANT 1 [4]

The result of the initial reference measurement is shown in Figure 2.

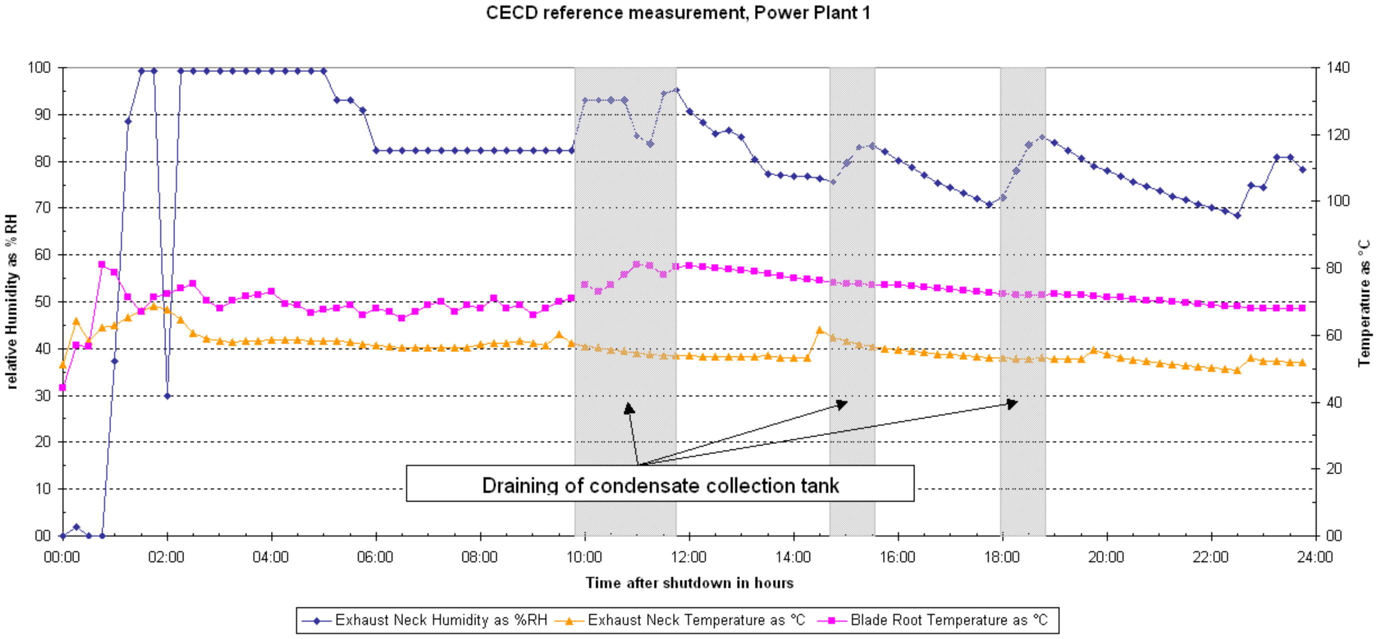

Figure 2: CECD reference measurement after usual shutdown of power plant 1

The pink curve with squares represents the temperature at the rotor surface in the blade root area, the yellow curve with triangles indicates the temperature characteristic in the turbine exhaust neck and the blue curve with diamonds represents the relative humidity trend.

The measuring results showed that an atmosphere fully saturated with water vapour was present in the exhaust steam immediately after the shutdown.

This condition still existed after a 6-hour standstill period. Only then, the relative humidity in the exhaust steam started to decrease.

Several times, a sudden increase was noted in the relative humidity trend (grey areas in Figure 2). Alstom experts identified the draining of the boiler condensate collection tank as the source of the increase. The boiler condensate developing during a standstill collects in the condensate collection tank. As soon as filling level "high" is reached, the tank is discharged automatically into the condenser hotwell. As a result, hot water of temperatures up to 85 °C enters the hotwell and causes an increase in humidity in the turbine exhaust-steam area. Due to the inflow of accumulated condensate into the feed-heater draining, temperatures of up to 75 °C were measured in the condenser hotwell. This is remarkably higher than the rotor surface temperature at the same time. It can be assumed that even condensation has occurred on the rotor at these conditions, forming an electrolyte film. Based on this, it is very likely that corrosion has happened under these conditions.

Considering these measuring results, a variety of changes were suggested and later on implemented with respect to the shutdown procedure. During further measurements with implemented modifications to the shutdown procedure other impacts, like leakages at valves became obvious. Measurements also showed, that some measures need to be repeated from time to time during a lay-up period.

It could be proved by a concluding measurement, that by analyzing the measured values and selective modification of the shutdown process, as suggested by Alstom experts, it is possible to influence the atmosphere in the turbine exhaust-steam area and reduce the humidity permanently during the entire lay-up time.

POWER PLANT 2 [5]

At power plant 2 the measuring equipment was mounted onto the turbine casing and activated whilst the unit had an outage for revision.

Figure 3 shows the results of the initial reference measurement. The measurement has been made 4 weeks after the unit had been put out of operation. This explains the low temperatures of some 25 °C. The printout clearly shows that using the unit's “standard shutdown procedure” the relative humidity had remained at to over 70 % during the whole standstill phase even after cooling down of the turbine to ambient temperature. Hence, a risk of corrosion on the turbine rotors cannot be excluded for the entire lay-up time.

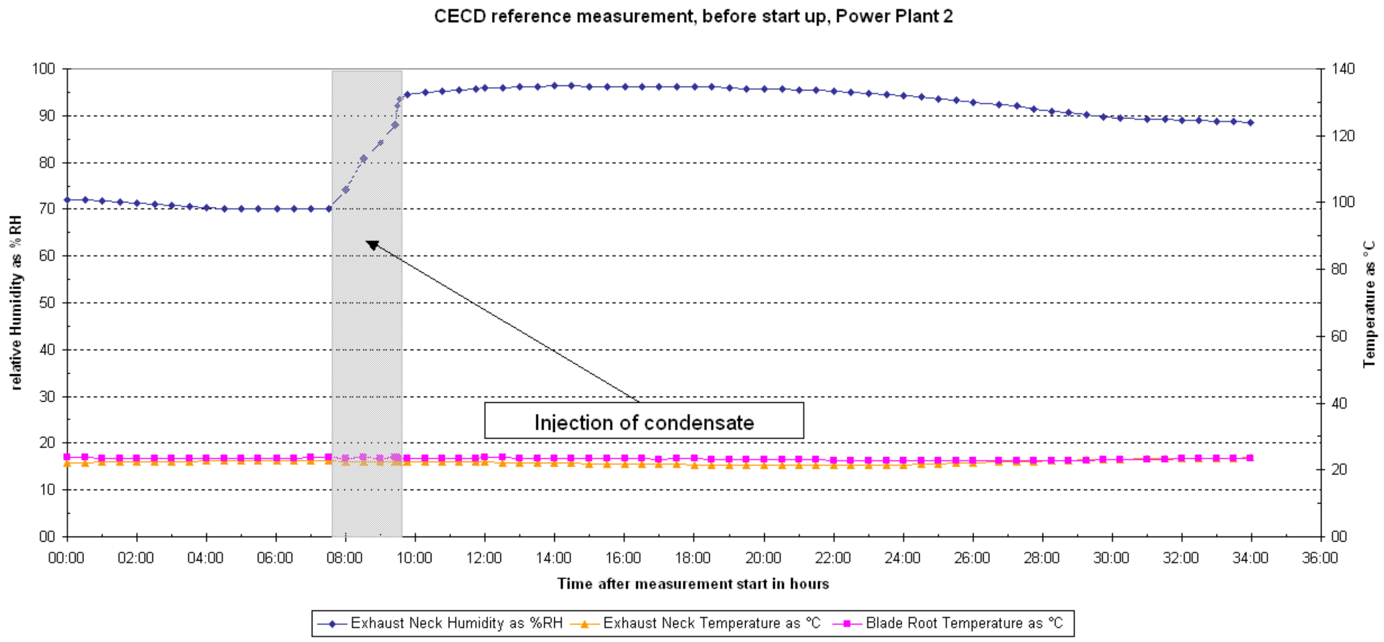

Figure 3: Initial CECD measurement at power plant 2

The measured temperature differential between the rotor surface temperature and the temperature inside the LP casing is less than 2 K. This value is in the range of the measuring accuracy of the used measuring equipment.

By injecting condensate via the hood spray equipment shortly before the restart of the turbine, the relative humidity was risen to more than 90 %. This intervention provides valuable information on the proper functioning of the system.

Since, at this point of time, the condensate had the same temperature as the LP casing, a relative humidity close to the saturation point (> 90 %) was expected, provided that the duration of the injection was long enough.

In Figure 4, the temperature and moisture curve during a shutdown procedure and for the following lay-up phase is shown. After the gland steam supply has been shut off, air was sucked into the LP casing for one hour, via the gland sealings, with 3 condenser vacuum pumps running. As a result, the water vapour in the LP casing was withdrawn almost completely and was replaced by the in-flowing air. The relative humidity inside the casing dropped below 10 %. A cooling effect on the temperature inside the LP casing is clearly noticeable during this phase. Towards the end of this phase of the process, the LP casing temperature even raised again and then slowly dropped during the subsequent standstill. The graph of the shaft surface temperature hardly shows an explicit cooling effect during this phase. It decreased steadily.

By increasing the suction capacity, it was possible to maintain a pressure of 0.45 bara in the LP casing despite the gland steam was shut off. This very quickly lowered the relative humidity in the LP casing below 40 %.

After the evacuating facility was switched off, the cooling-water pump was turned off and the vacuum breakers were closed, the relative humidity in the LP casing raised rapidly in the course of two hours to more than 60% due to the vapours that entered via the vacuum flash box.

About three hours after shutting down, an increase of the reheater pressure of the boiler was recorded. The LP bypass was then opened in order to relieve the reheater pressure. The diagram clearly shows this process by another rapid increase in relative humidity. By relieving the reheater pressure, it was possible to prevent a further increase. After about 2 hours, the relative humidity in the LP casing had dropped to approx. 40 % due to the condensation of water vapour in the cold hotwell. During the following cooling phase, the relative humidity decreased further to approx. 20 %.

After about nine hours after shutting down., the relative humidity in the LP casing started to rise again. This is again attributed to a pressure increase in the reheater. By repeating the pressure relief on the reheater, it was possible to reduce the relative humidity again, which had risen to about 30 %.

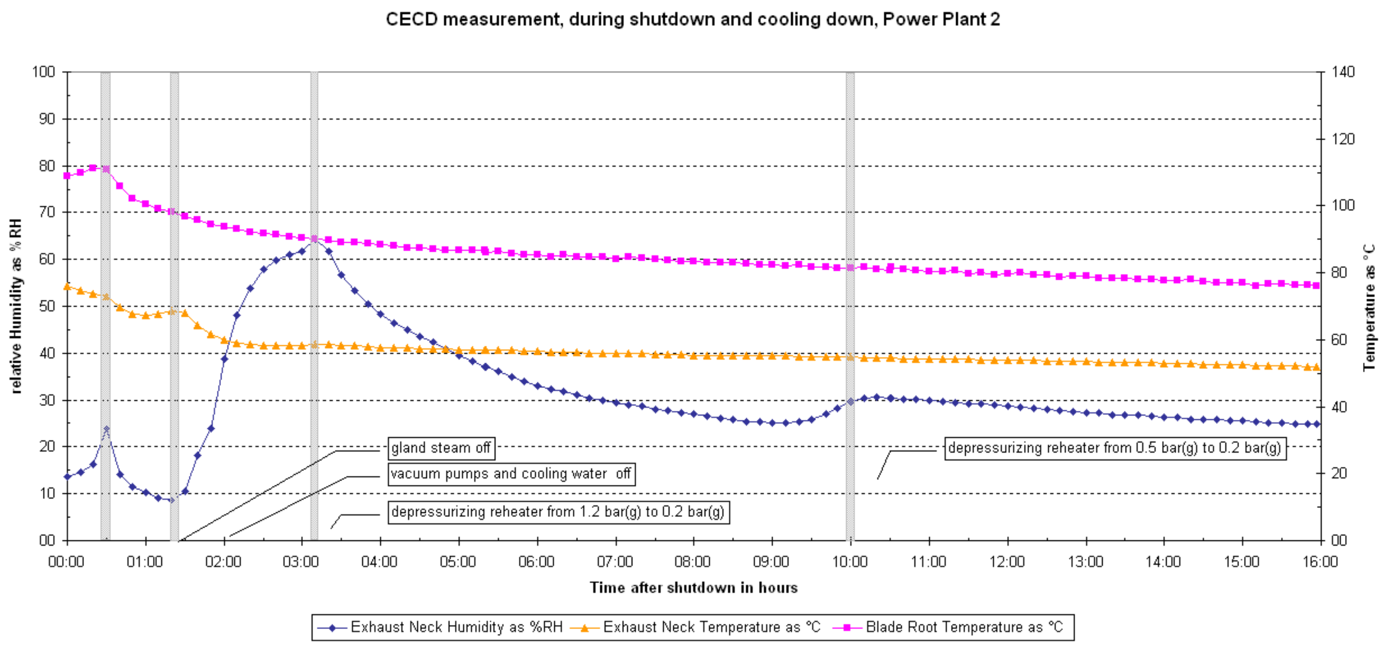

Figure 4: Exemplary CECD measurement during shutdown and cooling down period at power plant 2

The same phenomenon occurred again during a following measurement of another shutdown. After some downtime, the temperature in the vacuum flash box started to rise and vapours from the vacuum flash box got into the cold condenser. This again resulted in an increase in the relative humidity inside the LP casing.

Also at this power plant it could be proved by a concluding measurement, that the relative humidity could be reduced by specific measures, that had been suggested by Alstom experts

POWER PLANT 3

At this power plant, the CECD measuring equipment was also installed during an outage.

After the installation the first measurement was started and showed a relative humidity inside the LP casing of above 50 %. The result of the measurement is shown in Figure 5.

One hour later the first remedy measures were started, one condensate pump was started in minimum flow to cool down the content of the hotwell, the vacuum pumps were put into operation to remove the wet air out of the LP casing and one vacuum breaker was opened to make sure, that no air or steam would be sucked through the gland seals into the turbine. After those first measures, the relative humidity dropped rapidly down to 15 %.

About 4:30 hours after the start of the measurement a second vacuum breaker was opened whereupon the relative humidity increased up to 25 % and the temperature inside the LP casing dropped noticeably. This effect could be explained by the inflow of air from the machine house. The temperature drop at the measuring point prevails the influence of the lower temperature and higher water content of the machine house air compared to inside the LP casing, hence overall the relative humidity increases.

Approximately two and a half hours later, all before mentioned measures were stopped and the relative humidity stabilized in a range between 35 % and 40 % relative humidity for the following 21 hours.

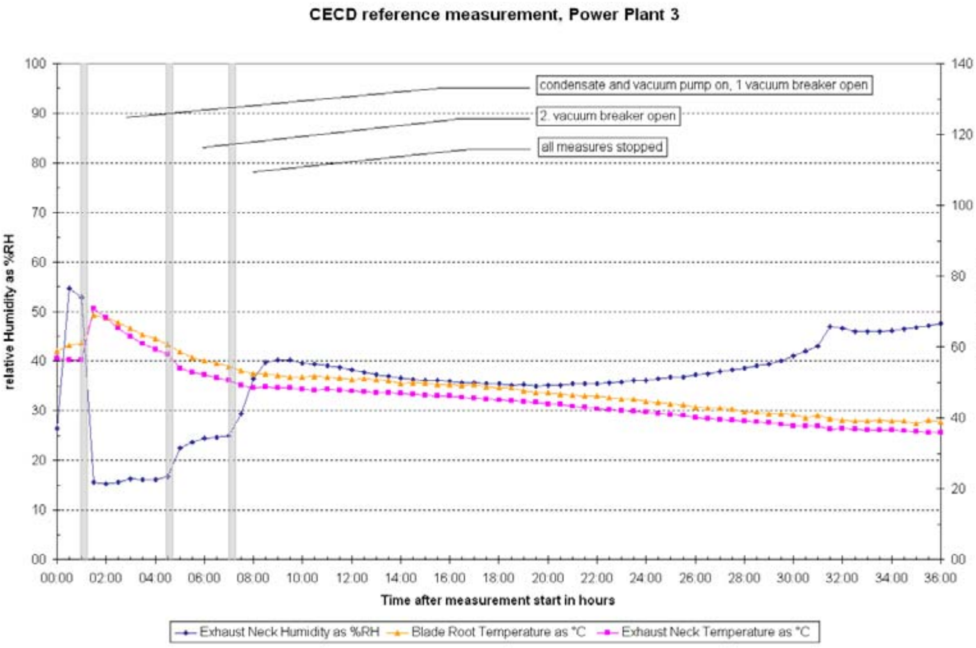

Figure 5: Initial CECD measurement after installation of the equipment at power plant 3

After accompanying measurements during shutdowns and implementation of several further modifications, a concluding measurement was realized. The results of this measurement are shown in Figure 6. After break of vacuum, the relative humidity inside the LP casing is increasing up to 70 %. At this point, the vacuum pumps were started and small vacuum breakers were opened. Additional, venting nozzles, installed at the bypass from the IP to the LP turbine, were slightly opened. The installations of those venting nozzles were part of former recommendations from Alstom experts and have been installed in the meanwhile. The venting nozzles can be beneficial in several ways. They avoid air flowing through the gland seals into the LP casing, the air is heated up by the LP turbine and thus can catch-up a lot of more humidity. And the venting nozzles allow cooling down the turbine more uniformly. After those measures, the relative humidity dropped down to 30 % and stabilized on a low level. The fluctuating values at this time can be explained by steaming out from the shaft seal of the turbine control valve from time to time. One and a half hour after shutdown, the condensate pump was stopped and the relative humidity could be kept below 40 %. A further one and a half hours later, the vacuum pumps were switched off, the venting nozzles closed and the gland steam condenser ventilation was switched on. By applying this measure, accruing steam from the gland steam header and control valve shaft sealing can be collected and will not steam out into the LP-casing via the gland seals.

At this point it became obvious, that there was a big amount of steam that could not be condensed completely at the gland steam condenser. That leads the Alstom experts to the assumption, that at several shaft packings there is bigger clearance caused by wear-out during the years of operation. In order to reduce the temperature exposure to the gland steam condenser ventilator, it was tried to remove the steam from the seal steam header by using the overhead flash pipe, instead of using the gland steam condenser and in keeping a condensate pump running in minimum flow (about 4:15 hours after shutdown). The increasing relative humidity shows that this measure was not working as expected due to unfavourable routing of the overhead pipeline. Five hours after shutdwon, one condensate pump and the gland steam condenser ventilation were set in operation again. From this point, the relative humidity inside the LP casing was decreasing again and stayed continuously below 40 % during the following cooling down phase. In order not to keep a condensate pump running or to break the gland steam condenser ventilator, due to a thermal overload, it was suggested to find another way to remove the seal leak steam. For example by installing an air blower into the overhead flash pipe to suck the excessive seal leak steam away from the gland steam condenser.

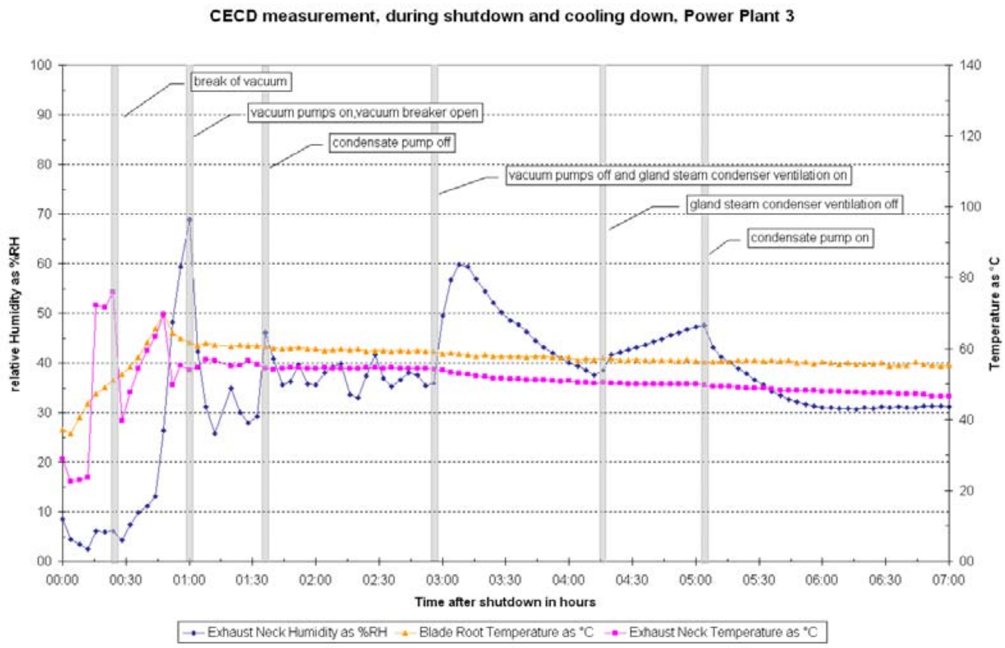

Figure 6: Exemplary CECD measurement during shutdown and cooling down phase at power plant 3

During another measurement at this power plant, at a certain point of the shutdown procedure a change over of the condensate pumps happened by mistake. This change over caused a small peak of the relative humidity inside the LP casing. That observation shows how sensitive and powerful this method is and how it can help to identify reasons causing a humid, and thus corrosive, atmosphere inside the LP casing.

CONCLUSION

The above-described examples are showing that the probability of corrosion during a standstill phase can be influenced substantially by modifying the shutdown procedure, thus reducing the relative humidity in the LP turbine casing. It was also shown, that “standard” shutdown procedures are not taking into account any aspect about corrosion protection or lay-up preparation for short standstill periods. Each time when the measurement equipment was installed at different power plants, a high relative humidity was present inside the LP casing. Shutting down the turbine with respect to a low relative humidity inside the LP casing could be the first step for an upcoming lay-up period.

The CECD method provides a set of measurements, these needs to be analysed by experts in order to be able to give recommendation on how to improve the shutdown procedure with respect to a following lay-up period.

The herein described examples show, that it is impossible to provide general suggestions for modifications. Modifications are always depending on the power plant and its specific configuration. This paper also shows, that CECD is an iterative process that usually requires three to four measurements. That means, that three to four shutdowns need to be accompanied by Alstom Experts in order to enable them propose suitable modifications of the shutdown procedure that helps to avoid corrosion-stimulating conditions.

It should be kept in mind, that due to, for example, wear-out, the condition of the power plant equipment varies and additional measures may be required. Based on this fact, it should be stated that it is also possible to have the measuring equipment (or parts of it) permanently installed. The permanently installed measuring devices can be implemented and activated automatically by the shutdown step program from the DCS. With those measured values, a lay-up time can be easily observed and after discussion with Alstom experts countermeasures can be applied if necessary.

It is possible to adapt the CECD measuring equipment to different types of turbines, independent from the manufacturer, what was already shown by discussed example of power plant three.

The CECD method is an important contribution to raise the availability of a power plant and helps to reduce the risk of any corrosion impacts on the turbine.

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