ICESP X – Australia 2006
Paper 8A2

UPGRADE TECHNOLOGIES FOR ELECTROSTATIC PRECIPITATORS

LENA LILLIEBLAD[1*] AND CHRISTER MAURITZSON[1]
[1]ALSTOM Power Sweden AB
P.O. Box 1233
SE-35112, Växjö
Sweden
[*]Correspondence to: lena.lillieblad@power.alstom.com

ABSTRACT

Electrostatic precipitators (ESP's) are commonly used for collection of particles in power plants and industrial applications. There are many ESP's around the world not meeting today's requirements due to aging, process changes and more stringent regulations for emission limits. Before ESP performance improvements can be considered, measures must be taken to ensure that the equipment is mechanically sound. Once this is accomplished there are various upgrade technologies available to improve the ESP performance. In order to choose the most appropriate upgrading technology it is necessary to have a good knowledge about the site-specific conditions. Measures can be taken to:

- Avoid or reduce the effect of high resistivity dust
- Reduce re-entrainment of dust caused by rapping or high gas velocity
- Change the mechanical ESP design by replacing internals and/ or rapping system
- Upgrade the ESP energy supply and control systems
- Optimize gas distribution and reduce sneakage
- Increase the ESP size
- Change the particle size distribution with agglomeration technologies

In this paper different upgrading techniques are described and compared both from a technical and economical point of view. A modern ESP control system is often a cost-effective method with a significant potential to reduce both emissions and power consumption especially at high resistivity dust conditions.

Exchange of old transformer/ rectifiers (T/R's) to high-frequency power converters have been successful in reducing the effect of corona quenching and allowing a higher T/R power input when severe space charge conditions prevails at high dust loads. Significant reductions in emissions have been observed.

INTRODUCTION

Electrostatic precipitators (ESP's) have been used for a long period of time to control particle emissions. Many ESP's around the world have been in operation for several decades. More stringent emission requirements and more challenging conditions due to fuel switching and other process changes result in a need for improved collection efficiency and ESP upgrade. Often it is sufficient to improve the performance of the existing ESP system by utilizing appropriate upgrading techniques. Another reason to invest in new ESP technology is reduced operating cost. An example of working procedure for ESP upgrading projects is shown in fig.1.

The present electrical and mechanical status in the ESP is determined by a detailed inspection. The inspection should be documented in a structured and accessible way. Broken or worn out parts are then repaired or replaced. Corrosion holes in the casing and ductwork are repaired and other necessary measures taken. Acceptable gas distribution together with good mechanical and electrical conditions in the ESP is prerequisites for successful implementation of upgrading technologies.

In the overhaul periods the gas distribution should be checked. Improper gas distribution can be devastating for the emission level due to:

- Small fraction of flue gas is not treated, the so-called sneakage, due to missing or improper baffles
- Stratification within the ESP casing with respect to flue gas velocity, dust concentration and flue gas temperature
- Unbalanced flue gas flow distribution between parallel ESP casings

The effect of unbalanced gas flow distribution between two casings is shown in fig.2.

The applicability and the possibilities with different retrofit technologies can be investigated, once the ESP is restored to its original condition. A simplified summary is presented in table 1.

This paper will deal with some of the available upgrading techniques.

Table 1. ESP upgrading techniques for an ESP in mechanically and electrically sound condition

Operating condition	Measure	Available techniques
High resistivity with back-corona	Cope with high resistivity	• Controllers with intermittent charging and advanced rapping control including tuning • Discharge electrode design with more even current distribution
	Reduce resistivity	• Conditioning with e.g. SO_3, NH_3, moisture or other agent
High dust re-entrainment	Reduce rapping losses	• Optimized rapping procedures • Modified gas distribution • Improved dust cake agglomeration e.g. conditioning with ammonia alone or in combination with SO_3 • Increased ESP size e.g. increased height or increased number of fields
	Cope with high flue gas velocity	• Reduce effects of corona suppression e.g. install peak electrodes or high-frequency power converters • Improved dust cake agglomeration e.g. conditioning with ammonia alone or in combination with SO_3 • Increased ESP size to achieve lower flue gas velocity e.g. increased height
Insufficient collection efficiency for upgraded ESP		• Increased ESP size e.g. increased number of fields • Change the particle size distribution with agglomeration techniques • Change to more efficient ESP design e.g. combination of ESP and fabric filter (FF) technology

CONTROL SYSTEM FOR ELECTROSTATIC PRECIPITATORS

Modernization of the ESP control system is often an efficient and cost-effective measure to significantly improve the ESP performance. A well designed and properly tuned control system is crucial for high ESP performance, long equipment lifetime and optimized power consumption.

A modern control system should be able to take care of:

- Spark handling
- Rapping optimization
- Intermittent charging (charging ratio)
- Self-optimization algorithm for best performance
- Power optimization
- Alarm handling
- ESP operation overview

The experience with modern control systems is discussed with respect to rapping optimization, high resistivity conditions and cost.

Rapping optimization

Rapping efficiency is important for all ESP applications and especially for high resistivity applications. A high resistivity dust layer on collecting plates reduces the ESP performance.

Improved rapping efficiency can either be reached by increasing the rapping forces or by decreasing the holding forces on the dust cake. Tumati (1993) made laboratory investigations on rapping efficiency with fly ash from a coal fired pilot-scale combustor. The rapping efficiency was defined as the percent of dust dislodged during one rap. The rapping efficiency increased with increased rapping intensity and ash layer thickness and decreased with increased current density. The rapping intensity has to be a compromise between rapping efficiency and ESP component lifetime. Lillieblad et.al. (2001) discussed the importance of proper design of the rapping system to get the best benefit of the applied rapping forces.

The electrical holding forces can be reduced by decreasing the dust resistivity by conditioning measures. Another possibility is to decrease or turn off the T/R power during rapping.

A feature in new control systems is to reduce or turn off the power during rapping for improved rapping efficiency. Combinations of ordinary rapping methods and power controlled rapping (PCR) should be used to achieve the lowest possible emission. The loss in efficiency in connection with PCR is compensated with increased overall removal efficiency. PCR is typically used every third or fourth rapping cycle and allow an overall lower rapping frequency, which will increase the lifetime of the ESP internals and reduce the maintenance costs.

High resistivity

Intermittent charging and efficient cleaning of the collecting electrodes are important tools in coping with high resistivity ashes.

Jacobsson (1996) presented a method, where the delicate task to select the optimum charging ratio and pulse current is controlled automatically based on data from the actual transformer/rectifier (T/R) only. This self-tuning possibility has been successfully introduced on many installations.

Some examples of implementation of control systems and tuning are presented. In the first example an ESP after a 630 MW_e coal fired boiler was optimized by using recent principles. The ESP was equipped with old controllers without PCR capability. The strategy was to avoid too excessive rapping and high re-entrainment during rapping. Improved spark handling increased the power input in the first field. Fig. 3 and fig.4 show the results from the optimization of the ESP after this coal-fired boiler. This limited effort reduced the emission by almost 50%.

In the second example the results from installations of new controllers in ESP's after coal fired boilers in India are presented. Indian coals usually have low sulfur contents and high ash contents. The ash has high contents of silicon and aluminum. A high resistivity fly ash is generated. Indian power plants have been upgraded with modern controllers to handle the high resistivity conditions. Emissions before and after the upgrade are seen in figure 5.

The emission is, for most power plants, reduced by at least 50%.

Cost

Wu (2001) reported in his review about costs for environmental control in coal fired power plants. The capital cost for ESP control upgrade was in comparison with most other upgrading technologies very low.

In addition the operating cost is decreasing for plants with high resistivity dusts, where the power can be substantially reduced and used much more efficiently with intermittent charging. If the PCR is used with less frequent rapping, it can in addition to an increased efficiency save the maintenance cost for replacement of wear parts.

The capital cost for ESP control upgrade could typically be around 0.20 Euro/ kW_e boiler capacity for a coal-fired boiler. The T/R power consumption could be around 1 MW without intermittent charging for a 500 MW coal fired boiler. Intermittent charging will for high resistivity fly ashes result in significantly decreased emissions. At the same time the T/R power consumption could often be reduced to approximately 20%.

Assuming a power cost of 0.035 Euro/kWh and 80% reduction in T/R power consumption, the investment will be paid in about half a year operation under these conditions.

CONDITIONING SYSTEMS

An alternative to cope with high resistivity dust is to reduce the resistivity. Different conditioning agents are successfully used. SO_3 is the most common conditioning agent and is mostly used for upgrading of existing ESP's and sometimes to help reduce the total installed cost of new ESP's. The ESP size can sometimes be halved for a plant with conditioning compared to a non-conditioned plant collecting high resistivity fly ash (Porle et.al., 1996). Ammonia is sometimes used alone or in combination with SO_3 (dual conditioning). Dual conditioning is especially used to avoid high dust re-entrainment during rapping in ESP’s with high flue gas velocities.

Conditioning for resistivity reduction is usually a more powerful upgrading measure for high resistivity fly ashes than T/R control upgrade with respect to emission levels, i.e.for the same ESP size lower emissions are reached for the conditioned ash than for high resistivity ash with intermittent charging and PCR.

The capital cost for the addition of a conditioning system could typically be ten times higher than for control upgrade. The operating cost will increase, since the T/R power consumption will be much higher in addition to cost for conditioning agents and power consumption for the conditioning plant.

POWER SUPPLIES

Efficient charging of the particles is essential to achieve high removal efficiency. It is important to achieve a sufficient power input. At high concentrations of fine particles the power can be significantly reduced due to corona suppression. This situation is applicable for example in the first ESP field, overloaded ESP’s in general and ESP applications with high concentration of fine particles. Increased power input is in these cases beneficial for the ESP performance.

Conventional power supplies generate a rectified voltage with the double mains frequency, usually 100 or 120 Hz. The voltage varies throughout each cycle. High-frequency power converters generate a voltage with negligible ripple, which will result in higher currents and improved charging. Modern high-frequency power converters have similar control possibilities as other modern control systems with respect to intermittent charging and PCR. Ranstad et.al. (2004) reported the results from upgrading projects with replacement of conventional power supplies in part of ESP's or in complete ESP's. Substantially reduced emissions were found for applications handling low to medium resistivity dust. Also applications producing high concentrations of fine dust (corona suppression) experienced significant improvements. The high-frequency power converters are now available at power capacities up to 120 kW, which will significantly increase the applicability of these power supplies for upgrading projects.

The cost for high-frequency power converters is generally higher than for upgrading of the control system only, but is still small compared to other alternatives, e.g. ESP extension and conditioning. It is a very cost-effective measure for the appropriate projects. The high-frequency power converters are usually easy to install, typically not requiring the ESP to be taken out of operation. The operation cost will increase slightly due to the increased power input.

ESP MECHANICAL DESIGN

The ESP mechanical design has to be suitable for the actual task. As previously discussed it is essential to have an efficient rapping system, where the applied forces are used in an optimal way.

Discharge electrodes like spirals and ribbons are superior to peak discharge electrodes with respect to current distributions along the collecting electrodes. It is desirable to have an as even current distribution as possible especially for high resistivity applications, where back corona condition needs to be minimized. In other cases, e.g. high corona suppression in front fields, low power input might limit the performance. In such cases peak discharge electrodes with their high emitting capabilities could be favorable. Adjustment of the discharge electrode design to the prevailing conditions could be very beneficial for the ESP performance.

A more compact ESP design is currently under investigation. ALSTOM has a license agreement with ERDEC Company Ltd in Japan. The expectations are a more compact design implying lower emissions for a given ESP casing volume. Back (2006) describes the status of this work in more detail.

REMOTE OPERATION

In many plants there are frequent changes in operating conditions like load and fuel, which influence the conditions in the ESP. A supervisory control system allows remote ESP support and troubleshooting. Stored ESP data and actual ESP conditions could be made accessible by means of Intranet or modem. Specialists within the company or from the ESP manufacturer can remotely analyze the ESP conditions and suggest or introduce changes in the control system. Opacity data is registered and stored together with the ESP data and used for the optimization. Fig.6. shows examples of data displays from remote support.

Remote service agreements are often signed due to these possibilities, where specified emission levels and/ or power consumptions are guaranteed.

COST

The cost for four different upgrading technologies is estimated for a typical ESP after a 500 MW_e coal fired boiler. Both first cost and total cost including the effect of operating cost are considered. The relative costs are presented in figure 7.

The upgrading technologies are not fully comparable. The potential improvement for each technology has to be evaluated for the actual plant. In appropriate cases the emission can typically be reduced by 50% with the upgrading technologies except for conditioning, where further emission reduction is expected.

Upgrades of control systems and power supplies including tuning with modern strategies are inexpensive compared to competing technologies.

CONCLUSIONS

The most appropriate ESP upgrading action should be selected based on a careful evaluation of the conditions at the actual plant. Initially the ESP needs to be inspected and restored to original conditions.

Upgrading of the control system is often an inexpensive and effective measure to reduce the emission and operating cost at high resistivity conditions. High-frequency power converters is a cost-effective alternative, when the performance is limited by a low power input, e.g. due to overloaded ESP's or obsolete power supplies.

Conditioning could be an alternative for high resistivity cases, where further reductions in emission are needed in addition to what can be gained with improved control systems.

REFERENCES

Back A, Porle K, Tomiyama H and Nolin K; Investigation of the ERDEC-type ESP after an oil fired boiler; Planned for presentation at 10th International Conference on Electrostatic precipitator, Cairns, Australia, June 26-30, 2006

Jacobsson H, Thimanson M, Porle K and Kirsten M; Back-corona control with help of advanced microprocessor enhances performances; 6th International Conference on Electrostatic Precipitation, Budapest, Hungary, 1996

Lillieblad L, Thimanson M, Porle K and Jacobsson H; On dust cake removal in Electrostatic precipitator; 8th International Conference on Electrostatic precipitator, Birmingham USA, May 14-17 2001.

Porle, K., Bradburn, K. Bader, P; FGC as a Means for Cost-Effective ESPs for Low Sulfur Coals, 6th International Conference on Electrostatic Precipitation, Budapest, Hungary, 1996

Ranstad R, Mauritzson C, Kirsten M, Ridgeway R; On experience of the application of high-frequency power converters for ESP energisation; 9th International Conference on Electrostatic precipitator, Kruger Park, South Africa, May 17-21 2004

Tumati P.R.; Evaluation of ESP rapper performance and optimum rapping force; 10th Particulate Control Symposium, Washington D.C., The United States, April 5-8, 1993

Wu Z; Air pollution control costs for coal-fired power stations; IEA Coal Research. ISBN 92-9029-366-7, 2001

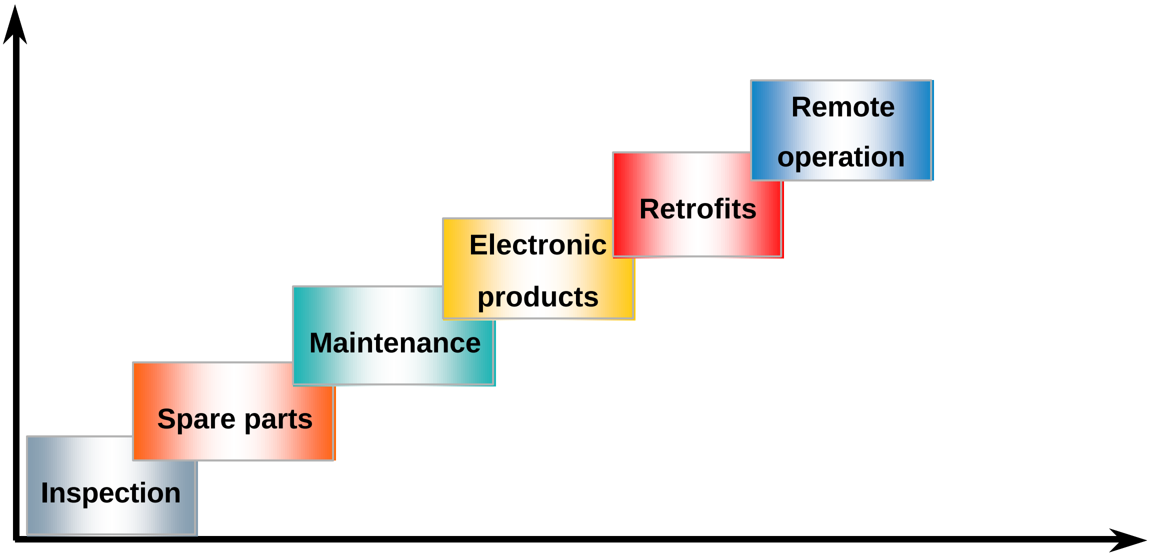

Figure 1. Working procedure for ESP upgrading projects

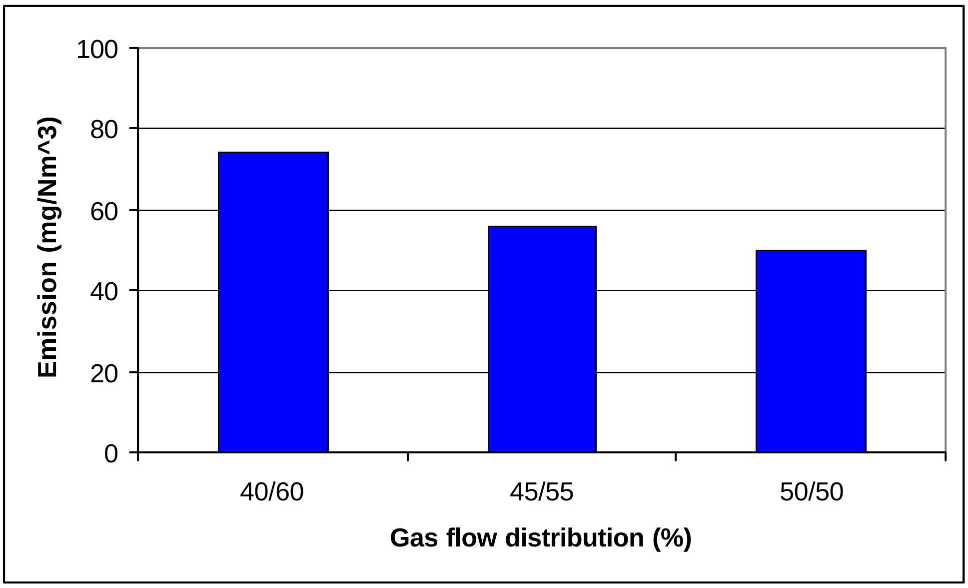

Figure 2. Estimated average emissions (mg/Nm^3) showing the effect of unbalanced gas flow distribution between casings after a coal fired boiler

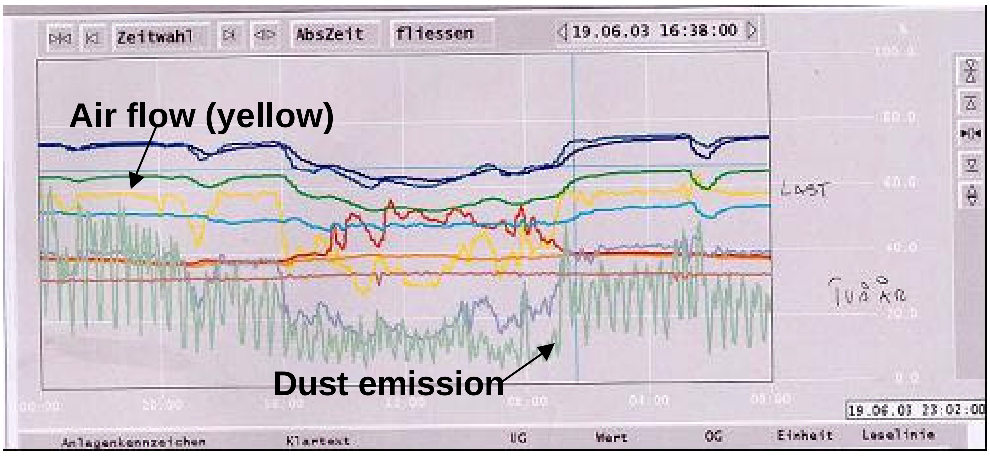

Figure 3. Dust emission before the tuning

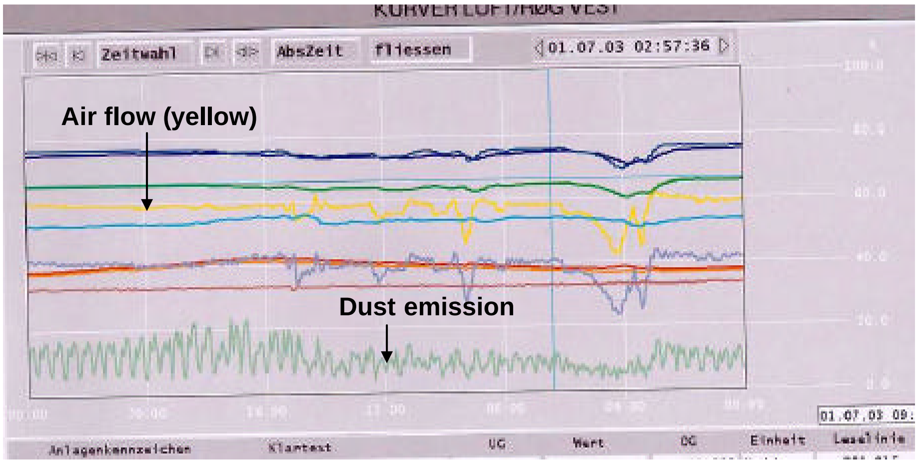

Figure 4. Dust emission after tuning

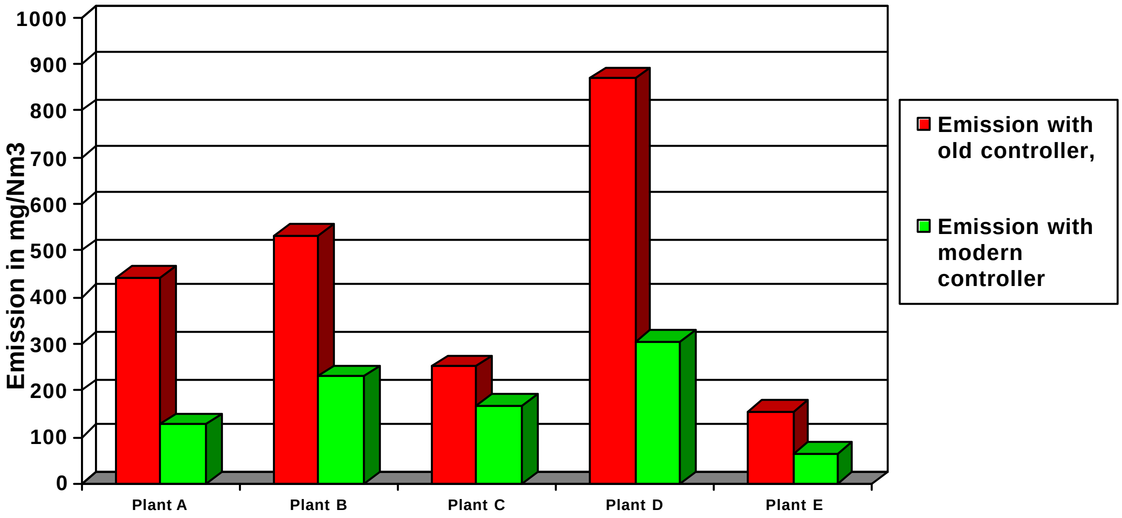

Figure 5. Emissions before and after upgrade with new controllers after coal fired boilers in India

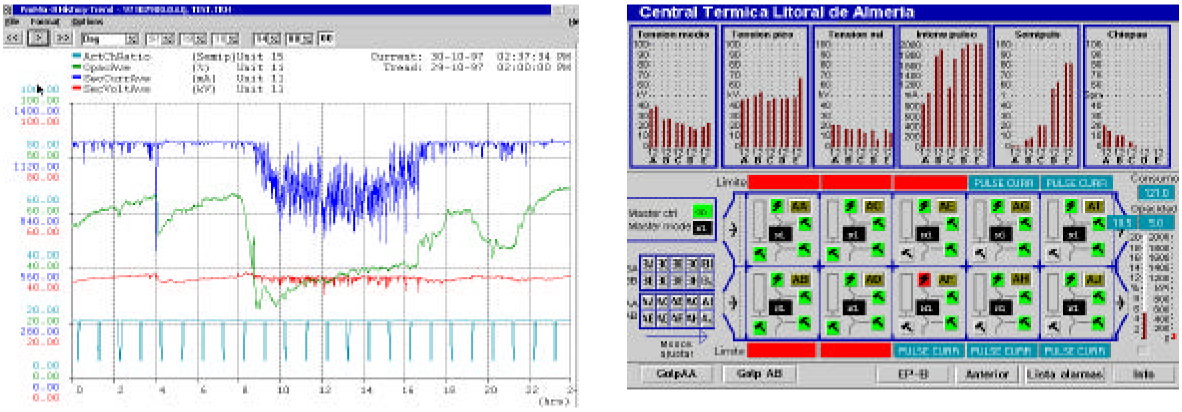

Figure 6. Example from remote support

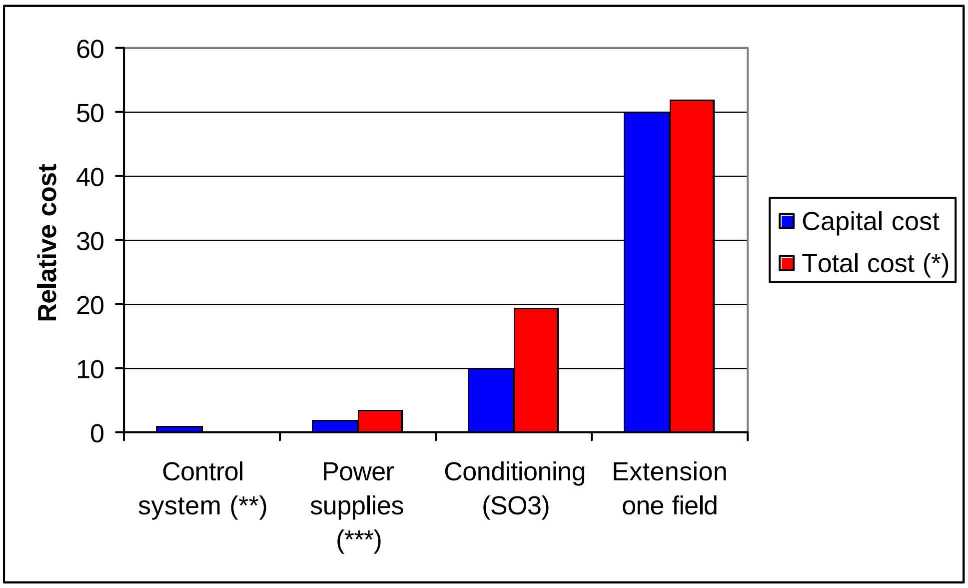

Figure 7. Relative cost for four different upgrading technologies using the capital cost for control system as basis (relative cost =1)
(*) Total cost includes evaluated cost for power consumption and consumables
(**) The capital cost for the control system is paid off due to reduced power consumption
(***) Power supplies = High-frequency power converters in the first ESP field