ON-LINE SUPERVISION SYSTEM OF UNIT ENERGETIC EFFICIENCY FOR COST REDUCTION IN POWER STATIONS

Pedro Gómez-Yagüe, José L. Albaladejo, Pedro Otero
ENDESA, S.A. - C.T. Compostilla

Antonio Copado
INERCO, S.A.

Abstract

The On-line Supervision System of Unit Energetic Efficiency is an advanced computer tool able to continuously calculate the global heat rate and individual efficiency of each relevant equipment of a power station unit. Its objective is the improvement of the unit efficiency offering to the plant operator a reliable on-line evaluation of the operation results.

Four relatively independent modules compose the system - data acquisition, quality assurance of process variables measurement, calculation routines, and graphical interfaces - which develop the following functions:

- Connection of the system with the conventional monitoring and supervision devices existing in the plant.
- Quality assurance of the received primary measurements by means of a structured set of validation filters. In the quality assurance module each variable measurement suffers a validation process composed by statistical analyses, recurrent signals evaluation, and coherence tests. The validation process ensures detection of anomalous values of variables and it is able to substitute them for their best allowable estimation. Therefore it has the fundamental mission of eliminating any source of error that can affect the calculated results of the system.
- On-line calculation of global and individual efficiencies and unit heat rate by means of high precision algorithms which satisfy and surpass the requirements of applicable reference standards (i.e. ASME PTC and PTC-PM).
- Evaluation of deviations in the operating results with respect to current plant objectives and to dynamic references punctually established by the operator. This function offers an immediate identification and quantification of the influence of each individual equipment or operating procedure over the global efficiency of the unit.
- Customised submission of the information to the different levels of the organisation, including, when appropriate, the translation of energetic results to economic data.

The On-line Supervision System of Unit Energetic Efficiency is already operative in the biggest units of Compostilla Power Plant owned by Endesa (350 MWe) as a relevant element of the programme for the continuous improvement of the efficiency currently in development in this plant.
1. INTRODUCTION

From the technical point of view, two of the most representative indicators of the quality of operation of thermal power plants are availability and performance. Although the historical tendency in Spain was more biased towards the first, performance should never be overlooked, otherwise, it deteriorates in a rapid and significant manner. As a reference, a degradation of 1% in the performance of a conventional thermal power unit of 350 Mw represents around 63 million thermal units. The bias towards efficiency is also justified by the intrinsically low performance of the thermal power stations. In addition to the limits imposed by thermodynamic laws, others have to be added such as: design values, modes of operation, equipment degradation and environmental restrictions, which almost always imply an increase in heat rate.

A high design performance is of little use if the thermal power plant is not operated in the correct manner. In order to keep close to this design performance level, it is essential that the following three circumstances coincide:
- To have the resources necessary for it.
- To have the feeling that it can be improved.
- To establish priorities and concentrate efforts on the reduction of controllable losses.

Besides, production costs must be known. This necessity is justified in two ways, both in the area of control:

1. The economic side. Knowledge of performances is the basis for accounting in the production of electrical energy of thermal origin. The fuel bill accounts for between 55 and 70% of the cost of production.

2. The technical side. To maintain high performances, as well as to improve them is, nowadays, rather than just a technological challenge, a necessity created by market demands.

The relations between these two ways must be such that:
- They are based on the same information.
- The information must be reliable.
- A slight improvement or malfunction in one part of the plant must be detectable and quantifiable in economic terms.

In any case, in order to reach the technical objective, there is an even higher level of requirements:
- There must be rapid communication and feedback information.
- The analysis of the results must be exhaustive.
- Personnel must be highly motivated and must have a plan of action.

The traditional manner of carrying out energy accounting in thermal power plants on a monthly basis can cover the economic objectives to a greater or lesser degree. In no way can it be valid for reaching a technical goal.

2. BACKGROUND

Throughout history, the desire to know performance levels has gone up and down. With increasing fuel costs, increasing competitiveness, and the appearance of taxes and environmental restrictions, interest has been growing. On the one hand, more efficient installations are designed; on the other hand, care is taken to avoid degradation of efficiency during operation. In both cases the necessity to measure arises.

The action of measuring efficiency in an objective and rigorous manner makes it essential to have available human and material resources that, in principle, increase operating costs. Therefore, it is necessary to justify this effort with whatever is obtained in exchange.
The liberalisation of energy production gives rise to even greater competitive requirements. Heat rate reduction, owing to the impact of fossil fuel on the structure of production costs, is an effective way of gaining market share.

The Compostilla Power Plant (Endesa), with its five units, is in its own rights, an example of technological evolution in the combustion of anthracite. During the first phase of its 38 years of life, the main concern was to maintain the units available. During the last five years, with unavailability below 2%, this preoccupation has been extended to include improvement of efficiency. In consequence, there has arisen the need for an update of the systems for the assessment of the results of the operation.

Years back, the time base for energy control was the same as for the technical and economic objective: it was monthly. There were established three loading intervals of the unit and two large systems: turbine cycle and steam generator. The heat rate of the turbine cycle was assessed on the basis of specific tests carried out in accordance with reception procedures. The results of these tests made it possible to establish the load-heat rate curve within design conditions. With this curve, the manufacturer’s data sheets, and the monthly averages of the main parameters, an average monthly heat rate was estimated for operating conditions. Performance values for the steam generator were obtained on the basis of calculations with the monthly average values.

The advantage of this method was its simplicity. Nevertheless there were inconveniences:

- The update of the turbine cycle heat rate is infrequent. It is done with data from a previous period and in conditions very different from those in which the unit was operating.
- Obtaining performance values with average data makes it impossible to detect tendencies and degradation. At the same time, because of the non-linearity of the process, the performance value expressed as an average of performance values differs from the performance calculated using the average of variables.
- The information that proves useful for the Operation and Maintenance departments is scarce.
- Corrective actions, if these exist, are delayed.
- The quality of important signals is not maintained.
- Detailed localisation of malfunctions is difficult.

We can conclude that the monthly base, though acceptable for energy accounting of a thermal power station, does not in any way cover the requirements of an efficient energy control of the installation, nor does it allow fine tuning of the supply to the market.

Given the magnitude of the industrial process that is considered here, one of the most notorious peculiarities is the sensitivity of the performance values to the different operating conditions in response to the incidents which are presented during operation. This same magnitude makes it impossible for the operator to know in an objective way, the effects of the multiple actions that are carried out.

Actually, the monthly base is maintained for the monthly economic reports but it has been reduced for the improvement of performance levels. The implementation of the process has been carried out in two stages:

1. In the first stage, the heat rate of the turbine cycle and the boiler performance was calculated on a daily basis for each load regime. The information so obtained was used as input for the monthly economic accounting and as technical feedback information. With this, the following advantages were achieved: an accounting based on the true behaviour of equipment and a higher degree of motivation of personnel.

2. In the second stage, which is now under development, the results of the operation enter into real time with specific follow-up for each one of the principal units. The reasons for adopting real time are the following:

   a) The design performance is not achieved if the plant is not operated correctly.
b) Correct operation is achieved if the repercussions of the deviations from controlled parameters are known.
c) Knowledge of the state of individual systems and components controllable by Operation and Maintenance departments is more effective than the case where only the overall performance level of the plant is known.
d) When overall performance drops suddenly, the detection of equipment causing the problem and the origin of the problem itself is rapid.
e) The monitoring of performances along with the use of historical files allow for detection of sudden and slow degradation.
f) The best way to control the influence of a malfunction or an incorrect measurement, or an improvement, is to detect it on time and to quantify its economic impact in a reliable and continuous manner.
g) It is necessary to know the deviation between the real value and the attainable value for each unit and for its principal parameters -in terms of overall energy consumption of the unit -, given the state of the equipment, to operate the plant adequately.
h) It is usual to have available on-line data acquisitions systems for the majority of measurements necessary.

3. OBJECTIVES

The fundamental mission of the system is to quantify the performance of the process (overall, and by individual elements) in real-time, reporting continuously on fuel consumption (cost) which is incurred, controlling the process of production. Other objectives to be met are:

1. To serve as an aid for the optimisation of the plant.
2. To homogenise the means of assessment of the operation and unify the energy accounting methods of the different power plants of Endesa.
3. To facilitate greater interaction of the operators with the plant through knowledge of the influence of their operating habits.
4. To make possible the implementation of expert diagnostic systems and aids for optimisation in real time.

4. PREVIOUS ACTIONS

Just having a monitoring system for performances is not sufficient to improve them. The information must be reliable. Then, it is necessary to have a system to assure the quality of information. To detect the relevant information it is necessary to carry out a sensitivity analysis of the plant data which allows the identification of the most influential signals in order of importance. Such a system is implemented in two phases.

The first phase must guarantee that:

- All necessary information is available in real time.
- All the measuring equipment, its location, installation and applications are adequate.
- Conversion and transmission elements are adequate.
- Instrumentation maintenance procedures are correct.
- The precision and bias are within the limits established for the calculation of unknown values associated with the performances.

Once the first phase has been covered, the second is to have available a system of surveillance in real time. For this, the monitoring software must possess the capacities of filtration and validation.

When the surveillance system detects erroneous data, it should be capable of substituting them with values which are more to be expected at the same time as it activates alarms for maintenance actions. The calibration of equipment and the follow-up of its drift must complete the system. With
this, a system will be available which is objective and capable of detecting small improvements or degradation, discriminating between cases in which there are errors of measurement.

4.1. Real-time Calculations

For carrying out performance tests for the different elements of a thermal power plant an abundant body of standards is available (ASME, ISO, DIN, NF, VGB, etc.), but none of these are applicable to real time. For this reason it is necessary to elaborate, check, validate and bring up to standard algorithms and alternative procedures which can eliminate this difficulty.

It is also necessary to know the deviation between the real value and the attainable value for each unit and for its principal parameters -in terms of overall energy consumption of the unit- to operate the installation in the most adequate manner. Thus, then it is also necessary to elaborate algorithms that establish reference values and assess deviations between these and the real values.

The continuous and accurate assessment of efficiency has its requirements in terms of instrumentation. In order to improve, it is necessary to begin by measuring accurately. Many of the signals that are required for this are also necessary for the operation of the plant; nevertheless, for permanent efficient operation, it is necessary to connect a larger number of signals. Some of the latter are not generally carried out in most thermal power plants, not only because of the cost, but also rather because of the complexity.

The monitoring should be conceived in such a way that it becomes an integrating tool for personnel. It should be so conceived as to be user friendly, promoting its motivation.

5. GENERAL SYSTEM DESCRIPTION.

The system that has been developed has the following as its basic functional aims:

I. To contribute to a more efficient operation, supervising and quantifying actions.
II. To serve as input for the economic control of the plant operation.
III. To serve as the basis for the assessment of the degree of compliance with the objectives established for the personnel of the plant.

For this purpose, the following capacities are available:

1. To make possible the improvements of operating habits.
2. To compare with pre-established references.
3. To permit off-line studies and simulations.
4. To elaborate off-line information for economic control.
5. To generate reference models.
6. To carry out acceptance testing and performance testing of equipment.
7. To have available all requirements which makes the system susceptible to auditing.
8. The information that the system generates is accessible over a network in a simple fashion.
9. To manage historical data files of the units including data relative to operation, results and deviations.
10. To make possible the conduct of parametric testing.
11. To permit the identification of the contribution of each plant component to the overall deviation between the true heat-rate and the forecast heat-rate.
12. To be flexible, scalable, and portable in a modular form for easy configuration in any unit on a user-friendly basis.
5.1. Detailed Description. Methodology Employed

The system consists of the following elements:

- Data acquisition module.
- Signal quality assurance module.
- Calculation module.
- Configuration module.
- On-line and off-line interfaces.
- Data storage elements: configuration file and case historical data base.

The system is conceived in such a way that it can be used autonomously at each unit where it is installed, while allowing interconnection of all the units among themselves through a central server which manages all the consolidated information (energy accounting of the production) of each power station.

The information that the system registers and/or calculates refers to:

- Variables and overall indicators of the operation.
  - Gross and net power.
  - Fuel consumption.
  - Auxiliary equipment consumption, electrical and thermal.
  - Boiler efficiency. Detailed breakdown of losses and credits.
  - Heat rate of the water-steam cycle of the unit.
  - References for each situation and deviations with respect to references.

- Accounting results of the power plant components.
  - Boiler. Efficiency, losses, performance of different sections.
  - Turbine. Overall efficiency per stage.
  - Air heaters. Efficiency, corrected temperature.
  - Heaters and de-aerators of the cycle. DCA and TTD factors, efficiency.
  - Feedwater pumps. Efficiency, curves, comparison.
  - Condenser and cooling tower; vacuum system. Efficiency, cleanliness factor.
  - Auxiliary steam.
  - Auxiliary electrical equipment. Equipment efficiencies, curves, comparisons.
  - Unit total

- Characteristics of the coal and other fuels consumed:
  - Data of proximate and ultimate analysis of fuels.
  - Daily data.
  - Accumulated data by month, year, etc.
  - Proportioning of fuel mix.

- Unit operation reference data:
  - Model in design conditions
  - Reference models in conditions of envelope boundary conditions.
  - Model of optimum attainable results.
  - “Consensus” model according to assigned technical objectives.
  - Deviations with respect to all of these.

- Environmental data obtained from Environmental Control Service.
Emissions. (Sulphur and nitrogen oxides, particles).
Air quality data.

- Start-up and outage data of the unit.
  - Typical or standard values. Optimum values.
  - Calculation of real consumption incurred.
  - Deviations.

The system is designed to maintain continuous on-line operation, with the potential to carry out other complementary tasks in off-line mode. The flow chart and connections between modules of the system in on-line operation are shown in Figure 1.

The off-line tool contains all the elements of the system configuration and the management of historical data, and it is based on the following data-processing modules:

- Calculations module.
- Configuration module.
- Off-line interface with the user.

This allows the system to carry out three fundamental tasks:

- System configuration
  - Management and update of the signal quality assurance system.
  - Management and update of the system of references.
  - Maintenance of the general system parameters, among those, the control of users.
  - Graphical management of addition/removal of measured and/or calculated variables.
  - Graphical management of adaptation to variations in the unit layout.

- Off-line running of the calculation module, allowing for simulations and tests, on the basis of historical data and manual entries.

- Processing of historical data for:
  - Obtaining the results of energy accounting in off-line mode.
  - Analysis of parametric tests.
  - Graphical analysis of plant operation historical data.
  - Analysis of case histories to obtain new references.

5.2. Data Acquisition Module

This module is charged with the role of establishing the interface with the surveillance system of each unit, selecting from all the real-time information of the process, only that which is necessary for the object of the application.

In order to be valid for all the possible systems of surveillance, the interface consists of the transmission, from the control system, of an ASCII file which is sent automatically every period of time, that can be configured by the user. This same method exists for the rest of the signals (emission, immission, meteorology, and fuel quality).

5.3. Signal Quality Assurance Module

Its function is to assure the quality of the signals whose values are required for the calculations,
validating them or replacing them with expected values. The module filters the measured values which are required for the calculations, using three complementary methods:

a) Statistical validation according to origin.
b) Validation by coherence (i.e. decreasing pressures in the cycle, increasing temperatures, balances of material and energy).
c) Validation by recurrence (in the most critical measures).

Besides, this module has the following functions:

− To assign a quality status to each input signal in relation with the results of the process of validation.
− To permit the optional substitution of measured values of signals which fail to fulfill the criteria of validation by expected value.
− Automatic update, on request, of validation relationships.

By its very nature and function, it is a module which is absolutely critical to guarantee the rigour and validity of the results. It is able to eliminate most sources of error involved in the process of determination of consumption, performance ratios, deviations, etc.

The system is based on statistical regressions and equations of balance, reinforced with the use of neural networks for dealing with the information and updating the filtering coefficients and validation.

The validation rules are formed on the basis of historical data through the following abilities:

− The ability to substitute measured values of non-validated signals with the most representative ones obtained from the application of the signal quality assurance system (neural networks and coherence rules).
− The ability to carry out network training and automatic update, on request, of system coefficients to match them with the actual state of the unit. Training is carried out on the basis of the values from the historical database obtained from the off-line interface.
− Differentiation of the state of a variable after passing through the system:
  . Faulty. If it does not pass validation and is not substituted.
  . Replaced. If it does not pass validation and is substituted.
  . Doubtful. If the system of validation is not able to catalogue it.
  . Good (OK). If it passes validation.

The signal quality assurance system can be activated or de-activated from the configuration module by the main user when this is necessary. Besides, this module can be configured, and easily accepts the inclusion of new signals in the configuration file.

When activated, it executes the following filters:

a) Statistical validation by origin.

This is based on statistical estimates of the value that can be expected of each one of the measured variables, for which we have recourse to the generation of neural networks (self-organising maps) which, from a determined input (vector of signals to be assured), allows the construction of the output which most resembles the actual input (vector of assured signals). The neural network presents, with respect to other statistical methods, the great advantage in that although the input in question may be incomplete or deteriorated by the noise which can exist in any industrial installation, it is still possible to obtain the output.

Each network is subjected to a learning process based on the vectors of input signals which are
previously assured, after which the assurance of the quality of signals is carried out by the
system in real-time.

The variables are arranged in terms of their location in the unit (boiler, turbines, etc.), in such a
way that each arrangement has a certain relation and is treated in independent sub-networks.
Thus, it is possible to break down the complex problem into a number of simpler problems,
opening up the possibility of combining different types of networks and of obtaining a system
which is reliable and accurate, operating in real-time.

b) Validation by coherence.

This consists of the analysis of the validity of the measured variables in relation to the degree of
compliance of the applicable thermodynamic relationships and the material and energy balances
of the sub systems in which they are involved. For each variable, admissible deviations are set
on the basis of the degrees of uncertainty associated.

5.4. Calculation Module

Its function is to carry out the calculation required for the determination of performance indexes, heat
rate, efficiency indicators, reference deviations, etc. And to operate both on-line and off-line.

Its main functions are:

a) To carry out on-line energy accounting quantifying the deviations with respect to reference
values established in relation to the state of the equipment.
b) To carry out, on request, an off-line energy accounting (energy accounting report), with analysis
of deviations.
c) To accept the establishment of references and external objectives through the configuration
module of the system.
d) To manage the historical files permitting simulations, sensitivity analysis and technical studies.
e) To assess the performance of the equipment which make greatest use of electrical auxiliary
services (pumps, fans, mills) and to compare with expected values or design values.

The main features are:

− Adaptation to the characteristics of each thermal unit.
− The use of standardised calculation algorithms that can be audited.
− Adaptability to changes of lay-out in the unit. The system detects equipment which is out of
service, and the calculations continue being valid. The incorporation of new equipment or
modifications are contemplated in the calculations through easy re-configuration of the
calculations using a Graphical Update Manager.

This being a system open to modifications and which can be audited, it incorporates a rigorous
system of control, follow-up and register of changes and older versions of the calculation model
with the aim of guaranteeing compliance with applicable procedures. For this, it permits access
and interactive modification by authorised users of the structure of calculation of each unit. This
structure is based on the following elements:

− Variables employed: these represent both measurements from the process as well as outputs
of the calculations. A variable is defined by name, value and units.

− Blocks: the system incorporates a set of blocks which allow for the realisation of any
calculation relative to a thermal power plant. The blocks can be:
  − Generic calculation routines, which can have different uses according to the input and
    output variables. For example, the sum of various values or the calculation of
thermodynamic properties of the water steam.

- Specific calculation routines, which contemplate all the peculiarities of the calculation procedures, for example: boiler performance, heater efficiency, etc. The specific blocks have function parameters to adapt them to each situation which may be presented (number of high pressure heaters, number of low pressure heaters, number of currents involved, etc.).

The system of blocks allows for the adaptation of the model of calculation to any layout, modifying the configuration file without the need to touch the system software.

- Curves: these store functional relationships of the type \( y = f(x) \), or \( z = f(x, y) \) between variables. For example: factors of correction, design curves for the equipment, etc.

- Calculations: these are every one of the elements which determine a result. Each calculation is determined by:
  - A set of variables of input and output to calculation.
  - Configuration parameters.
  - Blocks employed.

For different calculations the same block may be used simply modifying the input and output variables, or the configuration parameters. For example, the thermodynamic properties block can be used as many times as needed for different calculations, simply varying the values of the thermodynamic properties at input or the parameter which identifies the type of output calculated: enthalpy, specific volume, entropy, etc.

- Calculation model: the model of calculation determines the order in which different calculations are performed to obtain a representation of the unit operation.

5.4.1. Calculation algorithms

All the calculations, both of performance indexes and references comply with the on-line and off-line standardised calculation procedures for:

- Performance of the steam generator.
- Performance of the air pre-heaters.
- Measurement and calculation of diverse flows.
- Heat rate of the turbine cycle and turbine performance, overall and by sections.
- Condenser efficiency.
- Cooling tower efficiency.
- Pump efficiency.
- Fan efficiency.
- Heater efficiency.
- Net heat rate of the unit.
- Calculation of references for the principal magnitudes of the system.
- Results validation system.
- Calculation of deviations with respect to references.

5.4.2. References system.

With respect to the calculation of the reference systems, the following methodology is employed:

- Distinction between primary operation parameters (measured and normally employed as control and surveillance variables of the power plant) and derived reference parameters which are determined by the former.

- Working out the values of the primary parameters on the basis of historical data or as objectives of the power plant, according to the values of the variables which characterise the actual state of
the unit, for example: gross load and weather conditions. The values can be obtained with curves of the type $y = f(x)$, where the coefficients are obtained from historical data through the off-line interface, or they can be introduced manually.

− Working out the values of the derived parameters through the calculation module, or if design references are required, by means of correction factors according to the manufacturer’s curves.

− The system which consists of the primary parameters, the derived parameters and the remaining variables, must be coherent with the actual condition of the unit, and allow for the calculation of the deviations between this actual state and that which would exist under reference conditions.

5.5. Configuration Module

The configuration module makes possible the implementation and the matching of the structure of the system with the unit in which it operates. As a means of storing this information, configuration files are used.

The blocks of information which can be configured by the user are the following:

− Generic system parameters: quality assurance system activated/de-activated, time interval for data capture, time interval for averaging and for calculation, location and names of files, etc.
− Parameters for the different reference systems: constants or coefficients for the functions $y = f(x)$ which define the primary parameters of the system.
− Names and values of other variables necessary for the calculations, but not measured, and which must be entered manually, as for example: opening of manually operated valves and dampers, etc.
− Design of reports and graphics.
− Authorisation of users and definition of security levels: names, passwords, privileges, etc.
− Re-training of the signal quality assurance system.

The configuration module has its own graphical operating system which is user-friendly and interactive. This is one of the utilities of the system off-line interface.

− Signal quality assurance system: to enter/delete signals from the system; to configure the neural network, etc.
− Calculation model: to configure variables, curves and calculations of the model, using the blocks existing in the system.

The configuration module of the system has a Graphical Update Manager for carrying out these tasks.

5.6. On-line Graphical Interface

The mission of the graphical interface is to present in an attractive, comfortable and complete form the information which is relevant to the process, and/or manageable from the process. Its operation, simply by means of the computer mouse, allows the following functions to be carried out:

− Real time presentation of parameters and operating results for the unit.
− Real time presentation of deviations with respect to references.
− Creation and management of historical data.
− Preparation and printing of reports and graphics.

The information is structured on different screens, which correspond to each plant system which is distinguished in a unit (Figure 2):

− Boiler (furnace, convective sections and pre-heaters).
- Turbines.
- Heaters and deaerators.
- Turbo pump.
- Auxiliary steam units.
- Auxiliary electrical units.
- Condenser and cooling tower (if available).

Besides, it is possible to monitor on specific screens, the data relating to the environment, or other useful information.

The user interface is managed through a graphics menu with a hierarchical structure of the presentations screens, in such a way that it is easy to navigate through them, simply by passing from one level to another.

5.6.1. Basic structure of the screens

Each screen presents three zones which are clearly differentiated:

a) Data area (Figure 3): The system presents two different types of data for the different plant systems:
   - Parameters which characterise the actual performance of individual equipment, and which allows to distinguish, in the case of energy deviations, which device is responsible for such deviation.
   - Energy and economic deviations of each sub-system, evaluated on the basis of losses accounted for in the unit.

b) Summary: In this section, which is present in all the screens, a summary is shown of the most relevant information which defines the working condition of the unit (load, fuel consumption, heat rates and performance indexes).

c) Trend Graphing. The graphics show the evolution of the different variables during the last 24-hour period. The way in which the information is shown on the graphics, will be highly configurable, allowing for modification of variables to be represented, scales, axes, etc. It will also have in-built zoom functions, automatic insertion of variables, among others.

5.6.2. Follow-up of parametric testing

The system incorporates an utility for the follow-up of tests which the users can activate at any time. This function sets as references, the values of the different magnitudes at the beginning of the test and allows the graphical visualisation of the effect of any modification in a variable of operation on the behaviour of the unit. Additionally, while the parametric test lasts, the values of all the variables are stored in a specific file, which can be used to carry out a later assessment.

5.6.3. Other utilities

The system also incorporates utilities to export information to conventional micro-computing tools, and to permit communication with other systems.

5.7. Off-line Graphical Interface

The off-line graphical interface has the following utilities:

- Control over the processes to be carried out off-line:
  - Off-line simulations.
  - Acceptance testing of equipment performance.
Presentation of input and output information for simulations and tests, including the deviations and references employed.

- Calculation of new references in relation to the historical evolution of the unit.
- Presentation and analysis of reference values, updated with respect to previous values.
- The generation and analysis of reference parameters.
- Control of the configuration module of the system by authorised users.
- Preparation of all necessary information to complete the official monthly report.

Additionally, the off-line interface module has the same viewing screens and graphic representation as the on-line interface module, and from any PC in which this interface is installed, it will be possible to activate the option to receive in real time the energy accounting situation of the unit.

6. RESULTS AND CONCLUSIONS.

Units 4 and 5 of the Endesa’s Compostilla Power Plant were adopted as pilot units for the development of the system. Work began in 1992. The installation was totally operative for the users in January 1998. The experiences derived from its employment are highly satisfactory. Thus, the units have passed from an oscillating heat rate (in due to leaks, by-passed flows and other malfunctions detected) to another, stable heat rate, 2% lower. All this has been due to the unification of operating habits and maintenance routines adopting as a reference objective the measured heat rate. The credibility of the system is verified by contrast with the direct method of evaluation of coal consumption. All the coal which is burnt in the power station is delivered by lorry and by train, and is precisely weighed. The annual difference between the coal weighed and estimated is lower than 0.25%.

The results are so suggestive that the Endesa Group has embarked on a project for the implementation of the system described in all its power plants within its plan for competitiveness.

The success of the system are based on continued work, step by step, of a team that has gone on solving the problems detected and adopting the positive experiences of other systems. Key points to be highlighted are:

- The fine tuning of specific instrumentation for certain measurements which are difficult to execute on-line (carbon in ash, continuous blow-down, condenser cooling water flow, etc.).
- The elaboration of a quality assurance system for filtering and validation of signals.
- The choice of redundant measuring systems for calculated values (condenser cooling water flow, coal volume flow, air and gas volumes).
- Permanent contact with plant personnel.
- The elaboration of specific algorithms for on-line calculations in actual operating conditions.
- The employment of the capabilities that new information systems allow.
- The elaboration of a system to guarantee the quality of coal sampling and analysis.
FIGURE 1: On-line Supervision System of Unit Energetic
FIGURE 2: Main Window of the System

FIGURE 3: Heaters and Boiler Feed Pump Data Area