Development of a Coal Purchase Price Formula Using PMAX® and CQIM®

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Abstract

The recent liberalisation of the Spanish electric market has forced the utilities to be more competitive. One of the biggest costs in the electric generation is the cost of the fuel, and so the relationship between coal characteristics and power plant performance has become a topic of increasing interest to the utilities.

In this paper it is described a methodology that UITESA, as IBERDROLA engineering company, has developed to establish a coal purchase price formula which takes into account the performance of the power plant, in terms of energy production, and operating and maintenance costs. Those aspects are related to basic quality parameters of coal.

The methodology uses two specific software models. CQIM is employed to determine the generating costs of different coal blends that are burned in the target plant while PMAX is used to develop and refine the boiler model that CQIM needs to run. PMAX has also been used to validate CQIM predictions, as it was the first time that it was used with Spanish coals.

As a result of the methodology, a complete model for the prediction of the generating costs related to coal quality has been obtained. A coal purchase price formula has been obtained from this model.

Introduction

The advent of competition in the Spanish electric utility industry is enforcing awareness of important concerns in the power generation sector. Especially relevant aspects are those referred to O&M costs, environmental issues, and competitor analyses. Fuel quality plays an important role when considering those topics. One of the possible approaches to the problem consists of using specific software systems to analyse the impact of coal quality in the generation costs.

UITESA, after a preliminary analysis of different coal quality engineering based models, selected CQIM[1] for its application to IBERDROLA's Guardo 2 power plant. The main aim of the application of CQIM to that plant was the development of a coal purchase price formula, which would be proposed to its coal suppliers.

Nevertheless, CQIM needs to be configured and adapted to the plant characteristics, and this process requires a lot of information and knowledge about the plant configuration and operation characteristics. UITESA had previous experience in the modelling of Guardo 2 power plant due to the installation of a PMAX[2] system there. In addition to the experience previously acquired about the plant performance, the PMAX system has been used with two goals in the project. First of all, most of the boiler model inputs required by CQIM have been obtained from the PMAX model. This has been done instead of using a PEPSE[3] model because the PMAX model was already developed and it has proved to be good enough to the configuration of CQIM. Secondly, PMAX as a well-known performance monitoring system has been used both off-line and on-line to validate CQIM results. This was especially important, as there was no previous experience with CQIM applied to Spanish coals.

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[1] EPRI, Black & Veatch, Gas Research Institute

[2] Scientech, Inc

[3] Scientech, Inc

Development and validation of the model

The CQIM calculation treatment focuses on equipment performance impacts and fuel related costs associated with the combustion of alternative coals in existing power generating units [1]. To determine performance impacts and fuel related costs, the CQIM considers all major equipment affected by coal quality. One of the most important components is the boiler system. Its configuration took approximately half of the total developing time, and PMAX has proved to be especially useful there.

The boiler of Guardo 2 is a 350 MW down-shot boiler with radiant superheat panels along the upper furnace front wall, and ball tube mills, which burns different blends of anthracite and sub-bituminous coals. Prior to the start of the analysis, EPRI had to provide a CQIM version adapted from the Salt River Project version to accept the down-shot configuration.

The main efforts of the project were directed to the modelling of the boiler. The previous experience about the boiler configuration (acquired during the development of a PMAX model for the plant) was intensively used here. Also, PMAX was used off-line with different blends of coals to have a complete set of validation cases.

The blends employed to construct the validation cases were obtained from the average, worst, and best properties of all of the anthracites and sub-bituminous coal suppliers. The way to blend the coals was the production of optimal characteristics for the coal, taking into account the design characteristics of the boiler. Also, the production of the most usual blends that are burnt in the boiler of Guardo was intended.

In order to use PMAX off-line it was necessary to develop a method to calculate the unburned carbon in the ash from the boiler configuration and the properties of the coal. This is due to the fact that PMAX uses that value as a measured input while CQIM calculates it. After the revision of the standard literature, the model developed by Ugursal [2] was selected and adapted to the properties of Guardo 2 boiler and its coals. The calculation of the unburned carbon was included in a new c-point sequence.

The set of validation cases was also used to obtain a formula relating boiler efficiency to coal quality. The methodology employed was similar to that developed by Barrett [3], but in this project more advanced statistical techniques have been used.

During the development of the CQIM model, several trial and error attempts were made using the cases produced by PMAX. Finally, an accepted desk boiler model was obtained.

To accept the boiler model several comparisons between CQIM and PMAX predictions were made. The boiler efficiency formula and PMAX direct results were mainly used, but not only boiler efficiency comparisons were made. Pressures, temperatures and velocities of air, gases, water and steam were compared. Also, a methodology was developed to compare tube fouling and slagging costs using both software systems. The methodology employs a set of indexes defined by the fouling factors calculated by PMAX, and the fouling and slagging indexes more usually described in the standard literature. Although both software systems do not calculate the same kind of factors, the trends predicted by both systems were considered similar enough to validate CQIM results.

The boiler efficiency calculation differences were small and it was considered that they were well explained by the different unburned carbon calculation methods.

PMAX is also being used on-line at the power station in order to validate the model on site. Data obtained from the on-line monitoring system are being used to validate CQIM results about boiler efficiency, unit heat rate and components performance, when the whole set of coal data is known the day after.

The operation and maintenance, auxiliary, and derate costs predicted by CQIM were also compared to the real performance of the plant.

As a result of the validation procedure it was concluded that CQIM predictions are accurate enough to develop a coal purchase price formula.

Some of the most important CQIM predictions are shown in annex 1 for different coal blends.

Development of a coal purchase price formula

After the completion of a fully accepted CQIM model, several blends of coal were obtained from the annual averaged, best and worst properties of the coal suppliers and stored as its inputs.

CQIM was run using those blends as inputs. As a result, a set of generating costs and coal properties was obtained.

CQIM break-even costs calculations were used to get the coal cost ($/ton) of the different blends that made the generation costs ($/kWh) of all of them equal to the best blend. Each blend had then its coal characteristics and a purchase price that made its generation cost equal to the best blend. That way it was possible to obtain a coal purchase price.

Using statistical techniques to correlate the coal characteristics to the coal purchase cost a coal purchase formula was obtained. Stepwise regression analysis, and engineering judgement were used to obtain the price formula. The most important parameter in the formula, as it was expected, was the high heating value of the coal. Other parameters considered in the formula were the ash, the sulphur, the humidity and the volatile contents.

The possibility of including other coal characteristics in the formula, such as grindability, or ash fusion temperatures was discarded due to the difficulty of obtaining those properties for the individual supplies to the plant.

Conclusions

UITESA has developed a methodology that combines two advanced software systems devoted to the analysis of the performance of power plants.

PMAX has proved to be very helpful in the development of a CQIM boiler model, and in the validation of CQIM predictions.

As a result of the methodology, a complete model for the prediction of the generating costs related to coal quality has been obtained. A coal purchase price formula has been obtained from this model.

References

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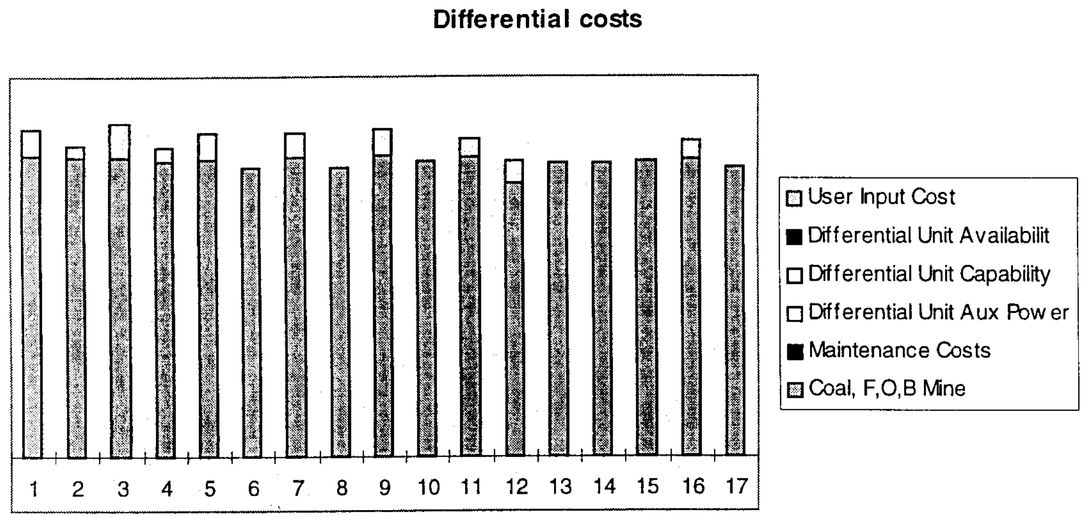
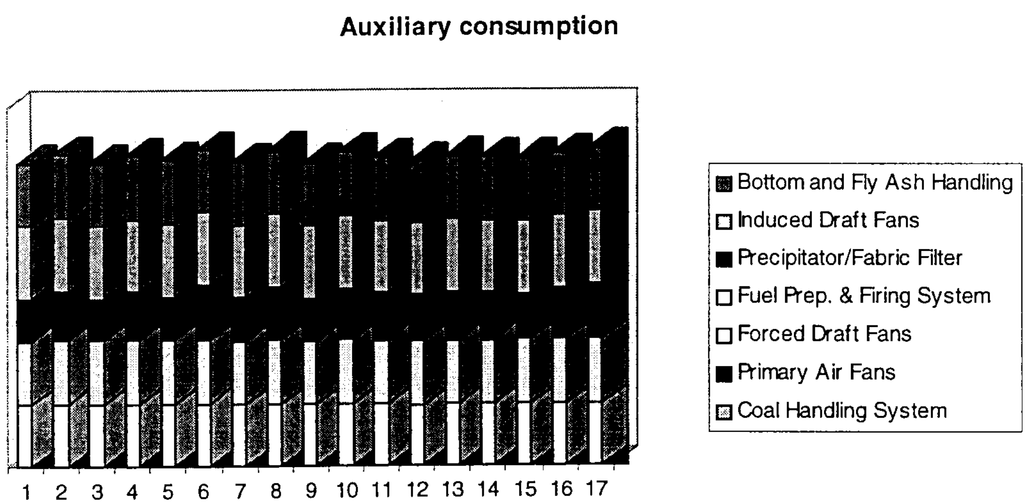
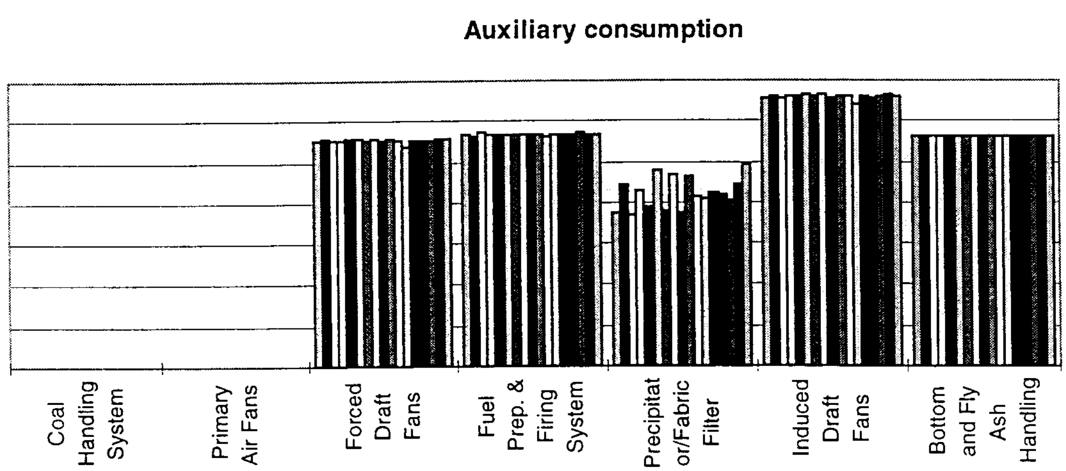
[2] Impact of coal quality on the cost of electrical power generation: a technoeconomic model. 1990. International Journal of Energy Research. Ugursal VI, Taweel AM, Mackay GDM.

[3] Power Plant Performance: Assessing the Impact of Coal Quality. 1983 SME-AIME annual meeting. Barrett R, Holt E, Mack G, Frank R.

Annex 1. CQIM predictions







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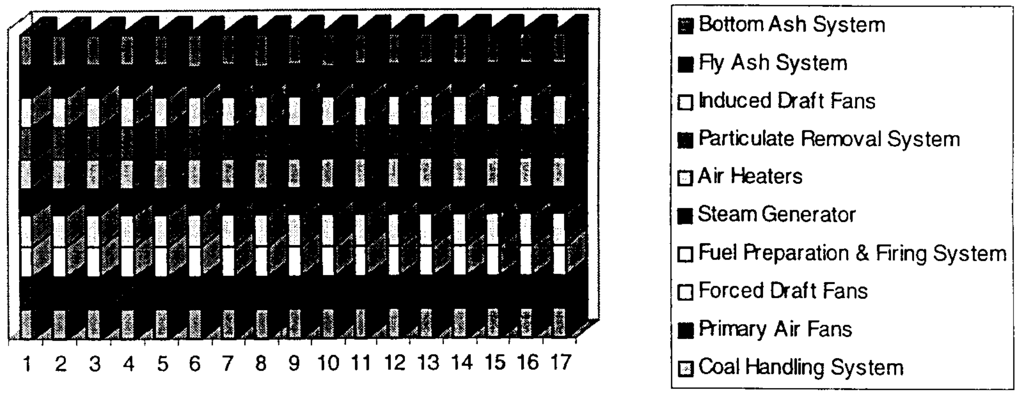

Maintenance costs