Achieving a Better Fuel Contents for a Coal-Fired Power Plant – an AHP Approach

M.-T. Hsu and C.-H. Wang

Abstract—In Taiwan, electricity generated by coal-fired power plants provides roughly 45% of domestic needs. However, it is well known that lots of waste was also released into the air as coal is burned to generate heat. The unsteady nature in coal composition makes emission control a difficult matter, and coal ore of different origins also exhibits quite distinct disparity. However, we have noticed in the control center most operators opt for maintaining a fixed, steady set of operation parameters. If one wishes to reduce unwanted wastes while not allowed to adjust the operation envelope greatly, then all he can do is try to mix and therefore alter the composition of coal a little.

In this study, a scheme based on the analytic hierarchy process (AHP) was adopted to determine for the most suitable range in coal composition from past operation records. The aim is to develop a strategy for mixing coal before entering the burner. The criteria of a best fuel is the one to have lower SO_x, NO_x, and particulate emissions while maintain a respectable power output.

***Index Terms*—analytic hierarchy process, orthogonal array, weighted analysis.**

I. INTRODUCTION

In Taiwan, electricity generated by coal-fired power plants provides roughly 45% of domestic needs. However, it is well known that lots of waste was also released into the air as coal is burned to generate heat. The unsteady nature in coal composition makes emission control a difficult matter, and coal ore of different origins also exhibits quite distinct characteristics as burned.

Baafi (1983) developed models that use the coal blending process to obtain high heating value and low sculpture content. His models are used for mine selection and to find an optimal amount of coal that needs desulphurization [1]. There were many reported that the source and caloric of coal has linear relations with power generation [2]–[4]. Naha *et al.*, Konnov *et al.* and Lee *et al.* proposed the power plant and the anthrax relations by no means power plant optimal fit [5]–[7]. Accuracy of immediate influence forecast to system generating cost and revolution reliable and security.

Scholars said “a good decision-making procedure”, is between the attribute and the feasible plan should be “objective” the correspondence; between the attribute and the decision-making criteria hard is “subjective” the correspondence. Saaty [8] reported that the main application and has in many appraisal criterion policy-making question in the indefinite situation, the AHP development goal is gives the question the system analysis, gives the level by the different stratification plane to decompose, and penetrates the quantification the judgment, finally gives the synthesis the appraisal, provides the policy-maker to choose the suitable plan the full information [9]–[12].

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II. METHODOLOGY

The systematical and analytical evaluation method of Taguchi quality engineering has been applied for processing parameters to evaluate purpose. The optimal experimental conditions and hence to achieve the highest systematic performance for mixing coal before entering the burner and the best robustness of quantization from the least number of trials in a batch laboratory scale.

AHP also uses a weighted average approach idea, but it uses a method for assigning ratings (or rankings) and weights that is considered more reliable and consistent. The research technique in this study depict in Fig. 1 AHP is based on pair wise comparisons among decision alternatives on each of the criteria. The following are 4 general steps for processing a decision problem, which includes

1. Decompose the problem into a hierarchy.
2. Pair wise compared to establish relative priorities among the decision alternatives in the hierarchy.
3. Synthesise the results (to obtain the overall ranking of alternatives relative goal).
4. Evaluate the consistency of judgement.

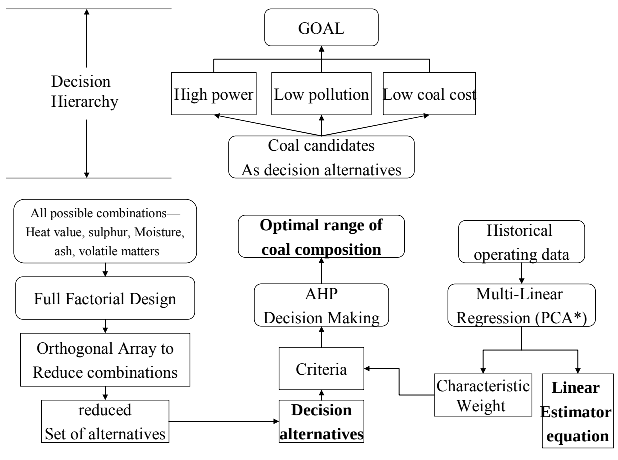

Fig. 1. The decision hierarchy and the research flowchart.

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III. Problem Definition and Handling

The thermal power plant in study use coals imported from several origins abroad, each with very distinct characteristics. Ideally, when the different coal is fed into the burner, the boiler parameters should alter slightly for better performance. However, it is not so, since most operators believe the slight difference in fuel contents does not warrant the need to alter operation parameters, especially for a facility that has been into successful operation for 20 years or so.

Now, the problem becomes quite simple, in which if the input changes, the output will change accordingly. By blending coals from different sources, we can manage to produce fuels with slight difference in composition. Since the proximate analysis were performed on each batch of imported coals, we decided to the 7 test items as variables which includes heat value (kcal/kg), ash content (%), volatile matters (%), sulfur content (%), superficial moisture (%), inherent moisture (%) and the fixed carbon (%).

In order to achieve a manageable problem size, each variable is segmented into 5 discrete levels. In a full factorial design of experiment, there will be 5^7 possible combinations, which is too large a sample size for either experiment or mathematical handling. Therefore, we used orthogonal array method to limit the problem size to minimal yet remain full coverage of all the possibilities.

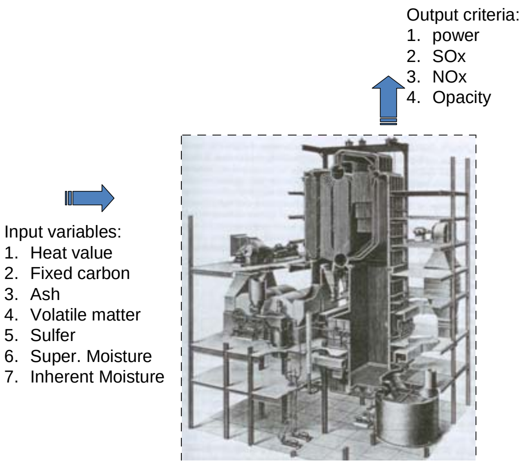

Fig. 2. Schematic drawing of the power plant with inputs and outputs [13].

The decision problem becomes as depicted in Fig. 2 in which we will try to find out how the output results are related or governed by the 7 input variables.

IV. Reliability Decision Analysis

Under the AHP rationale, the weight is an acting key role, the appraisal process and the result can receive the weight value to tow, but the weight obtains mostly comes from the expert advice and the questionnaire weight, although has the appraisal weight target, but belongs to the subjective weight; Saaty plans the hypothesis basic weight is 1, 3, 5, 7 and 9 appraisal scopes, if has the consideration again segmentation is 1 – 9 nine division appraisal scope, or other appraisal scope consideration, if establishes the weight matrix by 1 – 9 weight values, then $w_i/w_j = a_{ij} = r$ value will fall in 1/9 – 9 scope (ratio scales), the value disparity will present 15 time of differences, 1.66, 0.08 – 0.013 and 0.01 disparity quantities, this weight plan can create, the weight value 1 – 2 will contain mostly decides the scope, will be bigger along with the weight value, which weight scope won't its appraisal weight be easy to differentiate belongs to Fig. 3.

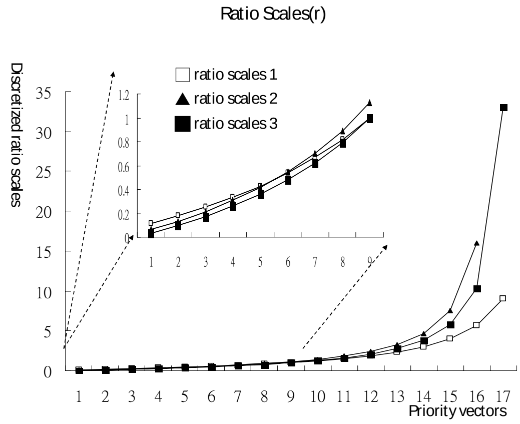

Fig. 3. Which (□ratio, ■ratio, ▲ratio)- Reliability decision analysis.

The level matrix, the a_{ij} relative value is $1/a_{ij}$, if a_{ij} is 1 – 9 scopes, the weight value presents 0.5 – 0.9 distribution, the weight 1 piece is 0.5, 0.66, 0.75, 0.8, 0.83, 0.85, 0.87, 0.88 and 0.9 presents like under the chart 7, weight 1 situation the weight value scales value hour, the weight difference is big, the opposite scales value is big when weight straight close; thought that this does not have the representation, and easy to create the appraisal the mistake, thus proposed that the weight equal theory, divides into equally 1 entire distance 17 equal parts, following chart weight 2 show, the value presents weight value each disparity 0.0588, from 0.0588 – 1 presents the equal weight, but because the weight value is 1, is unable to present the counter-weight value, when and further because scales is 1 weight 2 are 0.53, expected that is 0.5 by facilitates the appraisal characteristic and the comparison 0.53 revision. If take 0.5 as the initial station, scales entire distance 1 equal assignment, then presents the chart 7 weight 3 values 0.5, 0.559, 0.618, 0.676, 0.735, 0.794, 0.853, 0.912 and 0.971 treats as the level this new weight to analyze the weight hypothesis.

Presents the expression the weight value by a_{ij} = ratio scales, □ratio scales 1 corresponds weight 1,▲ratio scales 2 to correspond weight 2, ■ratio scales 3 to correspond weight 3, (writes in simple form a_{ij} = ratio scales r), has r_1 change difference in weight is by originally 0.5 – 0.9 scope, creates the r value falls in 1 – 9, new weight 2 the value fill-out are 0.529 – 1 sector, 1 cuts is 17 divisions (divides into 0 – 1 data 17 equal parts), in 0.529 changes into (substitution) 0.5, the data 0.5 + 1/17, will be r_3 this data in the future, each equal

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parts think 0.5 – 0.97, also if, because weight = 1 is not correct, because of w1 + w2 = 1, if therefore w is 1 piece of another w value is 0, is born again new r_3 will be 1 – 33 (on a fence data will substitute r = w2/(1–w2), may obtain Fig. 3 above this data. weight establishes the same distance (disparity), theoretically weight isometric correspondence r, should also be an equal-space, but new ratio scales 3 actually from 1 – 9 (or 1/9 – 1) change into 1 – 33 (0.03 – 0.79). ratio scales 2 may see presents 1.12, 1.42, 1.83, 2.40, 3.25, 4.66, 7.50 and 16.0 invalid value, but ratio the scales 3 pieces present 1, 1.26, 1.61, 2.09, 2.77, 3.85, 5.8, 10.33 and 33 as shown in Fig. 3.

Changes its hypothesis sector the weight judgment, hopes the appraisal process, will present one side the weight appraisal tendency the tendency, may give up rights the heavy value difference change to be remarkable, the characteristic will approach similarly weight, may also underline, will let the overall analysis even more have the representation. Corresponds a_{ij} = ratio scales also presents the wide range, by originally 1 – 9 transforms 1 – 33 sectors, then changes the weight characteristic.

V. Policy-making Management

At present we have been able to push estimate various units best coal-burning ingredient scope. This scope must coordinate the power plant the operating type, and considers the import the intermediary to plant, should scope establishment loose, will otherwise have will not be able to match the predicament. Speaking of the revolution personnel, a more actual demand provides him to push by the anthrax ingredient estimates the electricity generation and the emissions result. This part may use PCA or the SVD method, and then discovers a group of linear relationship. The following namely pushes for some unit's linearity estimates the equation:

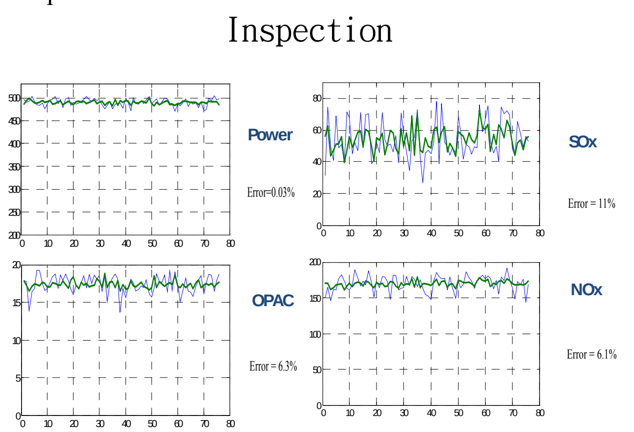

Fig. 4. Policy-making management analysis.

The first is a better combination of coals from different sources. The second is a set of multi-linear regression equations with which we can estimate the possible emission of the power plant. Two approaches were taken into consideration for the experiments, i.e., selective and collective parameters, and then the optimum conditions were sought for each considered approach Fig. 4.

(a)

$$POWER = .22X_{sw} + .01X_{hv} + .98X_{mw} + 1.13X_{ash} + 4.03X_{vm} + 55.5X_{s} + 4.63X_{fc}$$

(b)

$$NOx = -3.01X_{sw} - .026X_{hv} + X_{mw} + 6.96X_{ash} + 4.92X_{vm} - 36.2X_{s} + 2.76X_{fc}$$

(c)

$$SO_x = -4.493X_{sw} - .04X_{hv} - 3.35X_{mw} + 1.12X_{ash} + 6.73X_{fc}$$

(d)

$$OPAC = -.26X_{sw} + .381X_{mw} + .372X_{ash} + .243X_{vm} - 1.61X_{s} + .97X_{fc}$$

The achievement of this research has two key points, first is used the multi-objective decision making way, decides on the good mixed coal ingredient scope; The second is analysis the power plant unit historical data, establishes the emissions estimate program, causes the power plant revolution personnel to be possible to estimate the possible electricity generation and the emissions result before the use.

VI. Conclusion

In the study, there were 4 coal-fired boilers that wish to come up with the best blending method of coals before entering the furnace. However, we were also asked not to interfere in the daily operation or even recommend for drastic changes. All we have are daily operation reports and proximate analysis of coals.

Basically speaking, we were asked to answer a question that ought to be answered long ago, which is "what shall we burn today?" As long as the parameters are fixed, we can help the operators decide the blending ratio of coals every day. Points considered behind the decision process include:

1. desired power output,
2. reasonable SO_x, NO_x, and opacity emissions and
3. remaining coal inventory

The reason why AHP is chosen as the methodology for decision making is due its capability to handle both qualitative and quantitative in formations.

What is unusual in this study is an L_{125} orthogonal array (OA, seven factors in five levels) was employed to reduce the sample size from 5^7 to a mere 125. First of all, L_{125} orthogonal array is not easy to obtain, and secondly, most of works dealing with multi-linear regression usually follows with an optimization calculation rather than proceed with decision method like AHP.

We believe we have managed to solve the dilemma and achieve two major results. The first is a better combination of coals from different sources. The second is a set of multi-linear regression equations with which we can estimate the possible emission of the power plant.

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