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DESIGN OF EXPERIMENTS APPLIED ON A 360 MW POWER PLANT IN OPERATION: SURROGATE MODELING APPROACH

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Abstract. *Steam generators are complex equipment and a proper operation depends on the identification of their most relevant parameters. The present paper presents an approach to select and rank the operational parameters of a subcritical steam generator of an actual 360 MW Brazilian power plant fueled by Colombian coal. The steam generator and its three coal mills are gathered on a single system whose controllable parameters are identified. Statistical tools like Design of Experiments (DoE) and Response Surface Methodology (RSM) are used to identify the model main controllable parameters and interactions to then rank them by order of importance. The surrogate model based on the commercial software is built to simulate the system efficiency with seven controllable input parameters: primary air flow, pulverized coal outlet temperature, speed of the dynamic classifier, stoichiometry, excess* O_2*, secondary and primary air crossover duct pressure, ranked by descendent significance. The maximum relative deviation of that surrogate model compared to the software simulation is 0.0172. The operator attention must be kept on the most influential parameters, respecting their rank and initializing the alterations for a new condition always for the controllable parameters with a high effect on the steam generator efficiency. Finally, controllable parameters must attain the best operating ranges propose. The recommended operational ranges and order of operation by significance allows a precision action in order to achieve a new, safe, stable, and more efficient condition.*

Keywords: *Box-Behnken Design, Coal-fired power plant, Design of Experiments, Response Surface Methodology, Surrogate Model*

List of Symbols

$P1$ Primary air mass flow rate, kg/s

$P2$ Pulverized coal outlet temperature, °C

$P3$ Speed of the dynamic classifier, *rpm*

$P4$ Stoichiometry

$P5$ Excess O_2, %

$P6$ Secondary air crossover duct pressure, mbar

$P7$ Primary air crossover duct pressure, mbar

$S1$ Steam generator efficiency, %

1. INTRODUCTION

A coal-fired power plant is a complex system of interconnected processes that converts chemical energy into electricity. Its core is the steam generator, where heat released from the combustion process is transferred to the working fluid. Plant efficiency, fuel consumption, and capital cost are critically related (Annaratone, 2008; The Babcock & Wilcox Company, 2015; GP Strategies Corporation, 2013).

Power plant operation effectively takes place at the steam generator, as no other action on the remaining equipment can impact the overall performance to the same level (Annaratone, 2008; The Babcock & Wilcox Company, 2015). The control system handles plant stability, leaving the operator to manage controllable losses (GP Strategies Corporation, 2013).

An experienced operator knows the plant characteristics and develops its particular way of command that guarantees the system integrity and performance. Although effective, there is room for reducing variability and improving the system performance process standardization, by means of decision support tools. These tools may be based on computational representations able to simulate the system behaviour in a broad range of conditions, also called surrogate models. The one developed in the present work was based on the Design of Experiments (DoE) and Response Surface (RSM) methodologies to standardize the steam generator and its mills operation to suggest operating conditions to the operator. A sequence of maneuvers are provided indicating the controllable parameter that the operator must act and the respective value of operation. The procedure to conduct DoE is applied to the PECEM power plant, located in São Gonçalo do Amarante, Ceará. The proposed methodology can be applied to other generation plants.

2. SYSTEM DESCRIPTION

PECEM I [1] is composed by two independent sub-critical coal-fired power units of 360MW electric power output each. Three independent mills feed one steam generator with dry pulverised coal. In fact, there are four mills available but one of them serves as a backup.

3. SURROGATE MODELING TOOLS

Statistical methods do not allow anything to be proved experimentally, but they do allow to measure the likely error in a conclusion or to attach a level of confidence to a statement (Montgomery, 2013). Design of Experiments (DoE) and Response Surface Method (RSM) are proposed to build a surrogate model based in statistics.

4. DESIGN OF EXPERIMENTS

Design of Experiments (DoE) refers to the process of experiment planning, designing and analysis so that valid and objective conclusions can be drawn effectively and efficiently (Antony, 2014). The set of experiments to be performed is expressed in the form of a design matrix, according to a chosen experimental design.

DoE execution demands process knowledge and careful planning, including the determination of what to be measured in the experiment, the capability of the measurement system in place, which factors can be controlled for the experiment and the number of levels of each factor and its range. The most important issue is the choice of the highest and lowest levels, as they define the range of the factor (Antony, 2014; Mathews, 2005) to avoid risk and to guarantee safety to the operation.

5. MODELING APPROACH

The methodology proposed in the present work follows three steps: planning and execution of the experiments with DoE, model fitting through RSM, and result analysis to build a surrogate model representing the system. Particular attention was given to DoE, justified by the importance of the planning phase. The proposal methodology is described in Figure 1.

The planning and execution phase following the DoE methodology is highlighted in yellow, and according to Antony, 2014, is crucial to the success of experiments. The design matrix with the necessary experiments to be carried out at the power plant is defined, based on six steps. The control volume (step 1) defines the scope of the study and its boundaries, by selecting the whole plant or some sub-system, such as the steam generator. Steps 2 to 4 follow the well known DoE procedure, and allows to chose the experimental design method in step 5. It must balance the amount of experiments with the available time and resources to conduct them, by taken into account the factor types and nature, replication, and

[1] https://pecem.brasil.edp.com/en/power-plant.

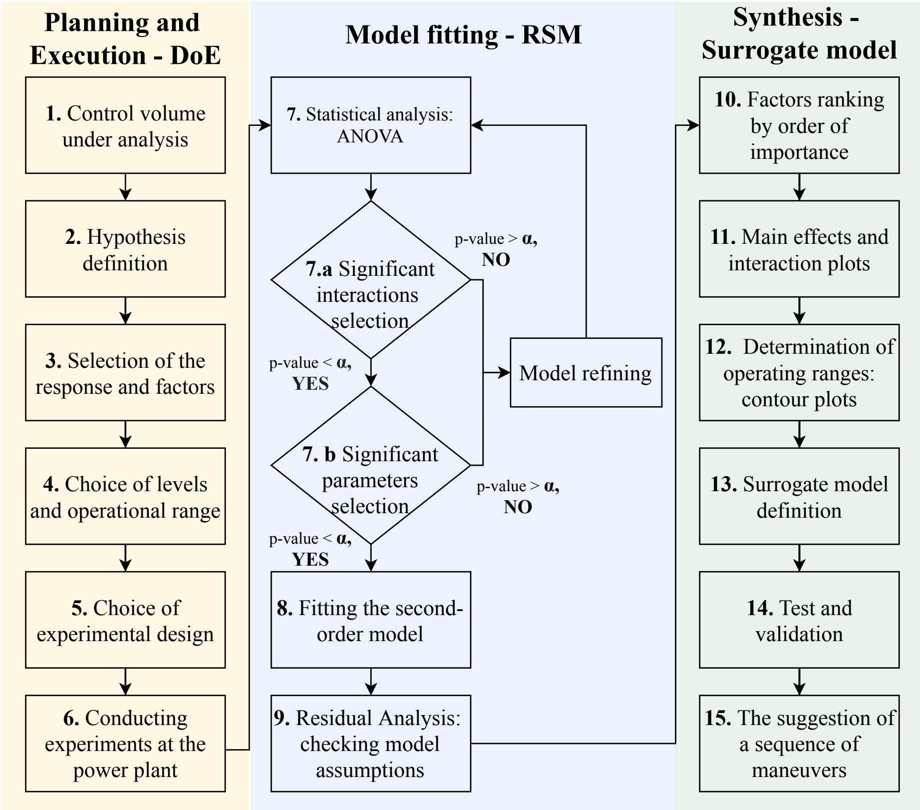

Figure 1. Step by step to the construction of a surrogate model to a power plant

blocking. The resulting design matrix contains the controlled factors, their levels and the experiment running order. The sixth step deals with procedures for conducting the experiments at the power plant.

In the case of system destabilization, the operator must return to regular operating conditions, for safety reasons. Any experiment that may cause an operating problem must be immediately suspended as safety is paramount. Results collection must be done at stable regime, i.e., when measurements do not change over time and not be adversely influenced by the operator and environmental changes (Antony, 2014).

The model fitting phase, highlighted in blue, builds a response surface model (RSM) out from the collected data. The seventh step employs Analysis of Variance (ANOVA) with the aid of MINITAB® to test the hypothesis defined at the beginning of the study, based on the definition of a confidence interval, and its complementary significance level (α). The interactions between factors are tested in step 7.a, starting with the higher-order interactions. The null hypothesis H_0 is rejected for p-value<α, meaning that the interaction is significant, otherwise (p-value>α) the interaction is removed from the model and the process restarted. This step is repeated until all remaining interactions in the model are considered as significant. Step 7.b tests the significance of individual factors. The null hypothesis H_0 is rejected for p-value<α, which indicates that the effect of a given factor is significant. At the end of the seventh step, only the significant terms according to the response remain in the model. It is worth mentioning that if an interaction of a factor is significant than automatically the factor remains in the model (even if p-value > α).

Step nine contains the residual analysis to check the model assumptions of normality, constant variance, and independence. Four residual plots are made in this step, namely normal probability plot, a histogram of residuals, residual versus fitted values and residual versus observation order. The simplest model that produces random residuals is a good candidate for a relatively precise and unbiased model. If some of the model assumptions could not be verified, the conduction of new analysis would become necessary. The possibilities include a missing variable, a missing higher-order term of a variable in the model to explain the curvature or a missing interaction between terms already in the model (Mathews, 2005; Montgomery, 2013).

The last phase, highlighted in green, builds a surrogate model to standardize the operation based on the analysis of the results of the previous steps. The first action concerns ranking the factors (controlled parameters) in descending order of importance in the response, in order to determine the optimal settings that minimizes variability. Key parameters are identified and ranked on a Pareto plot at the tenth step.

The 11^{th} step is the construction of the main and interaction effects plot to analyze factors behavior. This is necessary to determine the settings that yield the best performance to improve steam generator efficiency. Step 12^{th} settle operating ranges to divide the regions in which the important factors lead to the best possible response. The lines of constant yield are connected to form response contours using contour plots. These contours are projections on the interest regions (Montgomery, 2013).

The 13^{th} step defines the surrogate model as the final equation of the previous steps, which assures that only the significant terms are present. The 14^{th} step tests the proposed surrogate model to it is validation. New predictions are made at certain positions within the design space where no data points existed previously. At this moment it is essential to look at the results critically and use the subject knowledge area to evaluate if the results make sense.

In closing, the surrogate model is used in 15^{th} step to provide a sequence of maneuvers to the operator considering only the significant factors (controllable parameters). The operator order of action is defined according to the importance of the factor and the best operational ranges by factor are settled ensuring a standardized operation.

6. PECEM POWER PLANT: A LOGBOOK TO BUILD A SURROGATE MODEL

The modeling approach presented in section 5is applied to the case study of the PECEM power plant. Boxes depicted at Figure 1 flowchart are detailed and the new challenges that emerge during the process are discussed. The power plant assessment was carried out for the 360 MW eletrical output base load, as factor levels can display different ranges according to the plant load.

6.1 Control volume

The natural choice of control volume (CV) is around the steam generator, but mills were included as they are directly related to the system performance.

6.2 Hypothesis definition

The significance of the controllable parameters and their interactions are the hypothesis to be tested.

6.3 Selection of the response and factors

The selection began with the identification of critical process parameters. The steam generator efficiency was chosen as the unique response to be observed in the present work, among many other possible ones, because it can adequately resume the equipment performance.

The input parameters related to the steam generator operation and mills were listed and classified based on controllability. The controllable parameters by definition can be directly impacted by the actions of the unit control operator (GP Strategies Corporation, 2013). The selected input parameters (factors) were the primary air mass flow rate (P1), pulverized coal outlet temperature (P2), speed of the dynamic classifier (P3), stoichiometry (P4), excess O_2 (P5), secondary air crossover duct pressure (P6), primary air crossover duct pressure (P7). The controllable parameters P1 to P7 were situated in the schematic layout of steam generator and mills presented in Figure 2.

6.4 Choice of levels and operational ranges

The operating range of the selected factors (controllable parameters) are determined according to the plant history to provide safe and stable conditions. Experiments must not cause additional stresses to the power plant, but to standardize operation ensuring safety. Acquired data from Unit 2 were gathered for the electric power output within the range of 340 to 360 MW from January 2018 to May 2019, which led to 4738 registers with the seven selected factors.

Table 1 summarizes the main values collected for the controllable parameters for group 2 operating on the 340 to 360 MW range.

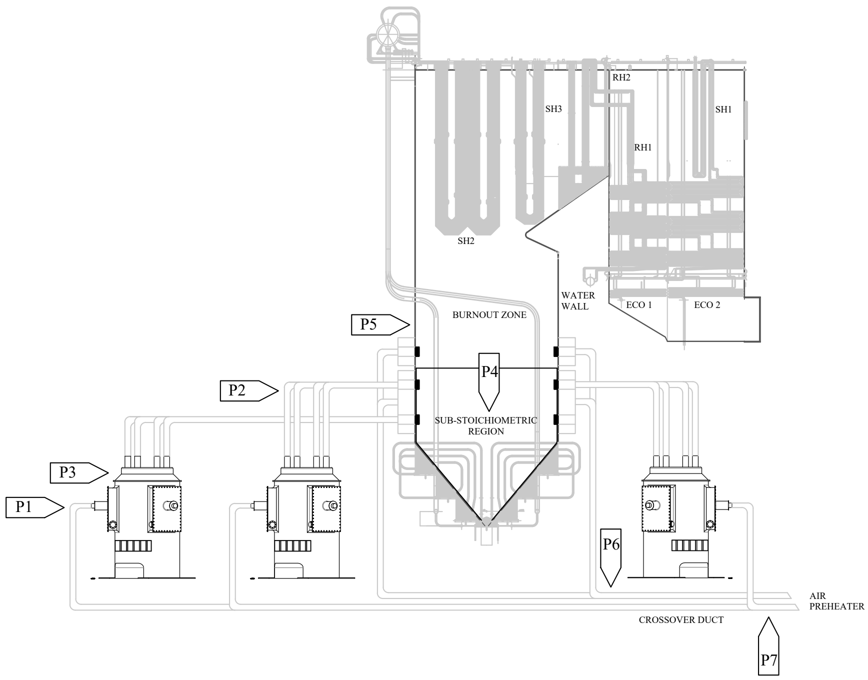

Figure 2. Controllable parameters location at the schematic layout of the steam generator and mills of PECEM power plant

Table 1. Summary of factors (controllable parameters) operation range and respective levels

Factor	Lower Level	Medium Level	Upper Level	Description
P1 (kg/s)	24.0	26.0	28.0	Primary air flow
P2 (°C)	65	75	85	Pulverized coal outlet temperature
P3 (rpm)	90	100	110	Speed of the dynamic classifier
P4 (dimensionless)	0.80	0.88	0.95	Stoichiometry
P5 (%)	1.5	2.3	3.0	Excess O_2
P6 (mbar)	18	21	23	Secondary air crossover duct pressure
P7 (mbar)	70	78	85	Primary air crossover duct pressure

The operational range of each parameter was defined with the assistance of the PECEM technical team, and limits were changed according to their experience and recommendations. It can be noticed that ranges are somehow limited but it always tried to reach the compromise of improving efficiency by respecting plant safety.

6.5 Choice of Experimental Design

The choice of the experimental design is directly associated with the costs and the available time for carrying on the experiments. The Box-Behnken Design (BBD) was chosen due to the required number of experiments. BBD stands out with only 62 experiments for 7 parameters whereas 3^k proposes 2187 experiments. On the top of it, BBD does not need to perform experiments at the range limits or extremes

Finally, blocking and replication were not considered in the study. Although replication reflects sources of variability both between runs and (potentially) within runs there was a limitation imposed by the technical team of PECEM power plant.

6.6 Real Life Experiments

The design matrix was proposed to the team in charge of conducting the experiments prior to its execution. It gathers all factor settings at different levels and their running order (Antony, 2014). It is important to assure a second approval from that team due to the technical and cost aspects.

The only required condition is that each and all factors must achieve the prescribed values. The prescribed values for factors P1 to P7 are hardly reached, but they must be in accordance with their corresponding uncertainties.External and non-controllable factors must be monitored in order to avoid interference in the steam generator operation. Steam generator efficiency S1 is released from the supervisory chart after reaching a steady state regime.

The controllable parameters were set one at a time, allowing to observe the development of the operation and to ensure safe control. Results of the performed experiments are presented in Appendix (Table 5).

Only eleven experiments out of the 62 planned ones were performed. These results are not conclusive and should be followed by a complete set of experiments.

7. SIMULATION MODEL AND ITS RESULTS

The proposed experiments could not be concluded at the PECEM power plant and were substituted by a simulation routine assemble with the aid of the EBSILON® professional software, which allowed to fulfill step number six of Figure 1. The simulation model showed to be capable of represent the system trend.

7.1 Model assessment

Simulated results from the EBSILON model were compared to the ones displayed in Appendix (Table 5). The relative deviation was calculated by the ratio between the efficiency difference of the PECEM plant and the simulation model in relation to the PECEM plant efficiency. The maximum relative values for each given case reached 1.21. It is worth mentioning that the execution of the experiments in the power plant in operation suffers a much greater impact from external variables than the experiments in the controlled environment in the simulation model, which may cause some divergence.

7.2 DoE applied on the simulation model

The simulation model was able to take into account all controllable parameters defined in Table 1 but the speed of the dynamic classifier (P3). The design matrix for the BBD method was downsized to 54 experiments keeping the same operational range. Results for steam generator efficiency (S1) are presented in Appendix (Table 6).

7.3 Statistical analysis

The seventh step is the statistical analysis with Analysis of Variance (ANOVA). Significant factors and interactions were selected by searching terms with p-value$<\alpha$=0.05, which reject the null hypothesis and corresponds to a minimum confidence level of 95%. Non-significant 2 way terms were removed one by one, followed by the square and linear ones. The interactions P1 with P4 and P1 with P5 were the only kept in the model after performing the interactions.

7.4 Fitting the second-order model

The eighth step is dedicated to the fitting of the steam generator efficiency (S1) second-order model.
equation 1 presents the final model containing only the terms statistically significant.

$$\begin{aligned} S1 &= 43.44 + 0.1604P1 + 1.22355P2 - 14.54P4 - 0.4101P5 \\ &- 0.128P6 - 0.0228P7 - 0.002193P1^2 - 0.007614P2^2 + 8.394P4^2 \\ &- 0.04651P5^2 + 0.003144P6^2 + 0.000147P7^2 - 0.062P1P4 - 0.01172P1P5 \end{aligned} \quad (1)$$

The final model displayed an adjusted R^2 of 99.98% and a predicted R^2 of 99.95% which can be considered suitable to calculate S1 (Salkind, 2017).

7.5 Residual analysis

The residual versus fitted values show a random distributed around the zero line with constant variance. The residual versus observation order plot shows no recognizable patterns or trends, and both NPP and histogram plots indicate that data come from a normal population. The present step concludes the second phase model fitting - RSM.

7.6 Factors ranking by order of importance

Ranking of the factors that influence variability in the response S1 is one of the major goals of the methodology. The Figure 3 presents the pareto chart of the standardized effects for the response S1.

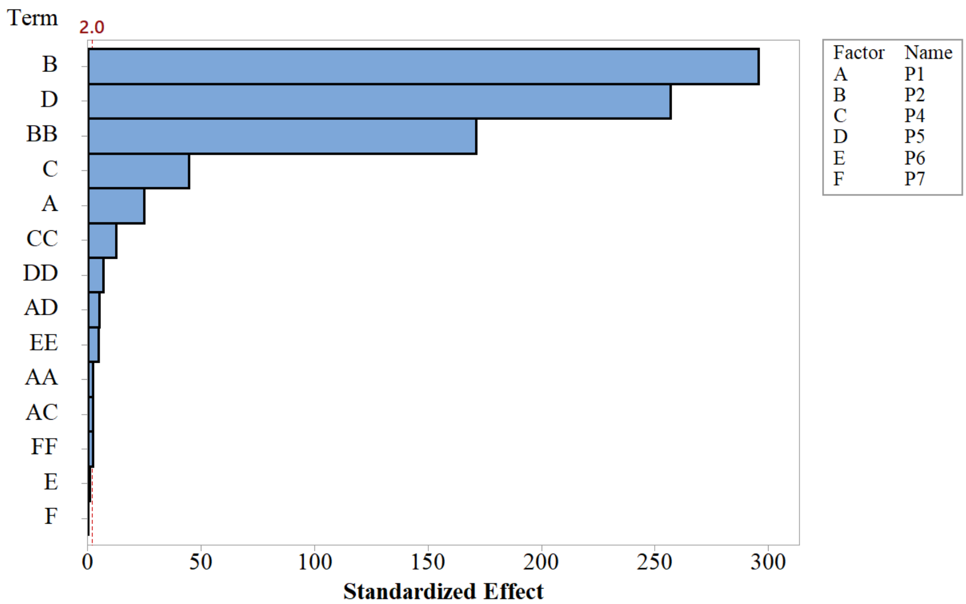

Figure 3. Pareto chart of the standardized effects (response S1, α=0.05)

The Pareto chart presents the factors ranked by order of importance, and by adding linear and quadratic terms of the coefficients. Factors by order of importance in respect to the system efficiency (S1) were the pulverized coal outlet temperature (P2), excess O_2 (P5), stoichiometry (P4), primary air flow (P1), secondary air crossover duct pressure (P6), and primary air crossover duct pressure (P7).

7.7 Main effects and interaction plots

Single effect on the steam generator efficiency (S1) in respect to each factor are displayed in Figure 4. Both a main effects plot and a Pareto plot are used to identify the key process parameters or factors which have an impact on variability. The slope is proportional to the effect. Factors P2 and P5 displayed a significant impact on S1 variation, confirmed on the former Pareto chart (Figure 3) which ranked the factors P2 and P5 in the first and second position, respectively.

The steam generator efficiency (S1) increases as the primary air flow (P1), stoichiometry (P4) and excess O_2 (P5) decrease. In the burning process, the more air is presented the greater the energy is used to promote the combustion. Regarding the pulverized coal outlet temperature (P2) the higher the temperature of the pulverized coal the better for the burning process. This temperature must be high enough to remove coal moisture, however, it cannot be so high as to cause the auto-ignition process. The condition of higher efficiency is around 80°C, corresponding to the nominal operating point of the mills. The parameters with the least impact on the steam generator efficiency (S1) are the secondary and primary air crossover duct pressure (P6 and P7). Despite being statistically significant parameters and remained in the model, the effect of P6 and P7 on the steam generator efficiency (S1) is much less than those of the other factors.

P1 with P4 and P1 with P5 were the only pair of factors that displayed significant interactions according to the hypothesis test. This interaction is in conformity with the physical process because the three factors are related to the total air flow in the boiler.

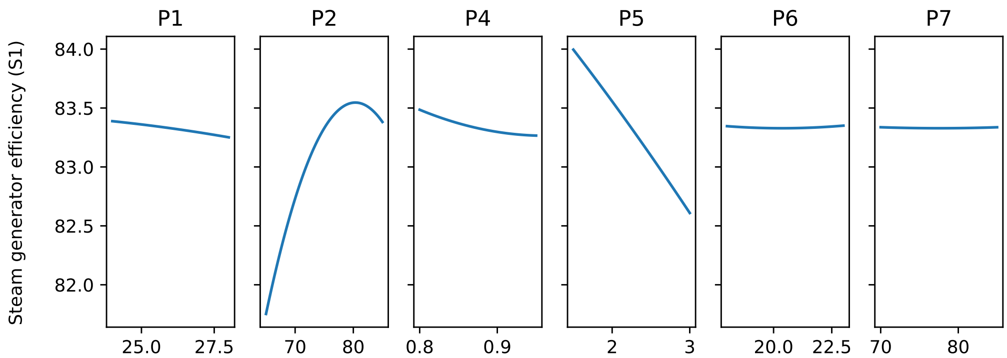

Figure 4. Main effects plot for the response steam generator efficiency (S1)

7.8 Surface and contour plots

Graphs are assembled by pairs of factors, while all others parameters are hold at their average values. Whole set of contour plots are presented in Figure 5.

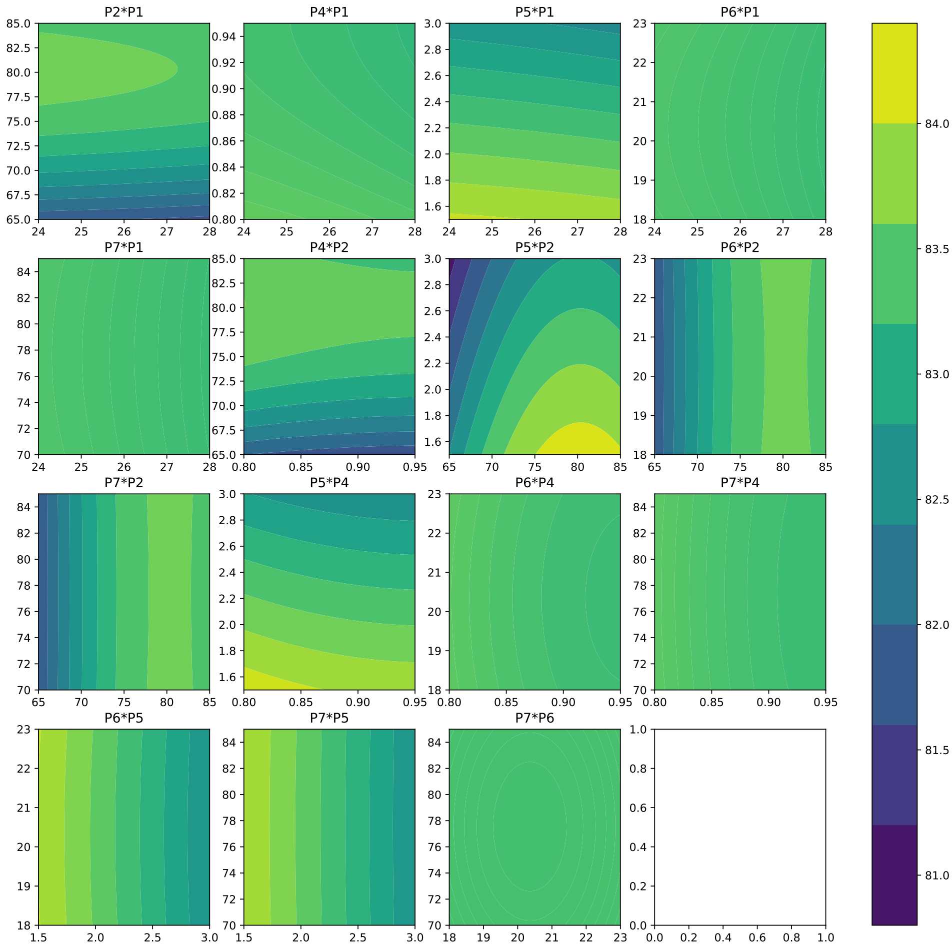

Figure 5. Contour plots of the pairs of combined factors

The pairs of combined factors with the greatest range of variation in steam generator efficiency (S1) were P2 and P5, P2 and P4, and P5 and P4, in accordance with the ranking of the factors (Figure 3).

7.9 Surrogate model definition

The surrogate modeling technique used in the present work was the Polynomial Response Surface (PRS) based on DoE and RSM. The second-order model was chosen to predict the steam generator efficiency S1, presented in Equation 1.

7.10 Test and validation

The generated surrogate model was tested for different situations and results were compared to the ones forming the BBD 54 experiments. In that context, the highest relative deviation was 0.0183. The generated response surface produces 20 predictions for new and untested operational conditions, willing to assess the model accuracy for unknown states, and results are shown in Table 2.

Factors were randomly varied to represent twenty new operational conditions. The maximum relative deviation was found to be 0.0172.

Table 2. Relative deviation of the simulation model and the surrogate model for 20 new operating conditions

Test	P1	P2	P4	P5	P6	P7	Simulation Model	Surrogate Model	Relative Deviation
1	26.0	75	0.80	2.3	21	85	83.48	83.49	-0.0002
2	26.5	76	0.82	2.4	21	83	83.33	83.40	-0.0008
3	27.0	77	0.84	2.5	22	81	83.19	83.30	-0.0013
4	27.5	78	0.86	2.6	22	79	83.05	83.20	-0.0017
5	24.5	67	0.90	1.7	19	75	83.77	82.70	0.0128
6	25.0	68	0.92	1.8	20	77	83.66	82.77	0.0105
7	25.5	69	0.94	1.9	20	79	83.54	82.84	0.0083
8	26.0	70	0.95	2.0	21	81	83.42	82.90	0.0063
9	26.5	71	0.90	2.1	21	83	83.36	82.98	0.0046
10	24.5	65	0.80	1.6	18	70	83.99	82.54	0.0172
11	25.0	66	0.82	1.7	19	72	83.85	82.62	0.0147
12	25.5	67	0.84	1.8	19	74	83.71	82.68	0.0124
13	26.0	68	0.86	1.9	20	76	83.58	82.73	0.0102
14	26.5	69	0.88	2.0	20	78	83.45	82.77	0.0081
15	27.0	70	0.90	2.1	21	80	83.33	82.80	0.0063
16	24.5	66	0.81	1.6	18	72	84.08	82.78	0.0154
17	25.0	69	0.82	1.6	19	74	83.96	83.31	0.0078
18	25.5	72	0.83	1.6	19	76	83.95	83.70	0.0029
19	26.0	75	0.84	1.6	20	78	83.93	83.96	-0.0004
20	26.5	78	0.85	1.6	20	80	83.92	84.09	-0.0020

7.11 Recommendation of a sequence of maneuvers

For the suggestion of a sequence of maneuvers there are no further constraints except the factors limits. The desired operational conditions to operate the steam generator efficiency (S1) are presented in Table 3.

Table 3. Optimum operational condition to maximize the response S1 - steam generator efficiency

S1 = 84.43%					
P1 (kg/s)	P2 (°C)	P4 (dimensionless)	P5 (%)	P6 (mbar)	P7 (mbar)
24	80	0.8	1.5	23	70

The steam generator efficiency varies from 80.80 to 84.43%. If the best operating conditions are defined as those with steam generator efficiency above 84% a set of input conditions can be chosen. Table 4 presents the possible operating conditions to guarantee steam generator efficiencies above 84% which is only possible for P2 above 75°C and P5 below 2.0%.

Table 4. Operation maneuvers to assure best-operating conditions

	P2=85°C and P5=1.5%			**P2=75°C and P5=1.5%**	
	Lower limit	Upper limit		Lower limit	Upper limit
P1	24	26	P1	24	25
P4	0.8	0.95	P4	0.8	0.9
P6	18	23	P6	18	23
P7	70	85	P7	70	85
	P2=80°C and P5=1.5%			**P2=80°C and P5=2%**	
	Lower limit	Upper limit		Lower limit	Upper limit
P1	24	28	P1	24	
P4	0.8	0.95	P4	0.8	
P6	18	23	P6	23	
P7	70	85	P7	70	85

8. CONCLUSIONS

The obtained algebraic expression (Equation 1) is capable of representing the steam generator behavior and suit as a surrogate model of the original system. The equation displayed an adjusted R^2 of 99.98% and a predicted R^2 of 99.95%. The model validation varied the factors randomly to represent twenty new operational conditions besides the reproduction of the 54 initial experiments. The maximum relative deviation was found to be 0.0172.

The factors were ranked based on their order of importance, where the first one has the higher impact. The most important factor was the pulverized coal outlet temperature (P2) followed by the excess O2 (P5), the stoichiometry (P4), primary air flow (P1), secondary air crossover duct pressure (P6), and primary air crossover duct pressure (P7). The use of surrogate models helps in drastically reducing the modeling time or experimentation hard to perform. The significant variables become decision variables to the operator. The surrogate model defined set the best-operating conditions and propose operation maneuvers to improve performance.

9. ACKNOWLEDGMENTS

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11. RESPONSIBILITY NOTICE

The authors are solely responsible for the printed material included in this paper.

12. APPENDIX

12.1 Results of the Design of Experiments applied on the PECEM power plant

Results of the performed experiments are presented in Table 5.

Table 5: Execution of the experiments at the PECEM power plant.

							Factors (controllable parameters)									
Date	Experiment number	Responsible operator	Adjustments start time	Adjustments end time	Experiment end time	Coal Stockpile	P1 (KKS)	P2 (KKS)	P3 (KSS)	P4 (KKS)	P5 (KSS)	P6 (KSS)	P7 (KSS)	Sampling	Sootblowing*	S1 (KKS)
8/12/2019	1	Operator A	11:36	13:05	14:20	2D	26.0	65	90	0.88	2.3	23	78		Sootblowing SH; start time 10:30 end time 13:40	91.20
8/12/2019	2	Operator A	14:20	15:23	16:24	2D	24.0	75	100	0.88	2.3	18	70	proceed sampling	Sootblowing primary SH ; start time 14:49	91.10
8/12/2019	3	Operator B	16:30	17:46	18:43	3A	26.0	75	100	0.80	3.0	23	78		Finalyzing sootblowing primary SH	90.90
8/12/2019	4	Operator B	18:47	20:05	21:05	3A	26.0	75	100	0.80	3.0	18	78		Sootblowing furnace; start time 20:03	90.30
8/12/2019	5	Operator B	22:25	23:10	0:10	3A	26.0	75	100	0.88	2.3	21	78		Finalyzing sootblowing SH	90.30
8/13/2019	6	Operator C	9:28	10:44	11:15	3A	24.0	75	110	0.88	3.0	21	78	proceed sampling	Sootblowing SH final; start time 8:42 end time 10:20	91.00
8/13/2019	7	Operator C	11:26	12:34	13:04	3A	26.0	65	100	0.88	3.0	21	85		Sootblowing stopped	90.30
8/13/2019	8	Operator C	13:58	15:22	15:38	3A	28.0	75	100	0.88	2.3	23	85		Sootblowing final; start time 13:26 end time 15:00	90.40
8/13/2019	9	Operator C	15:51	17:08	17:14	3A	26.0	85	100	0.88	3.0	21	85		Sootblowing stopped	90.10
8/13/2019	10	Operator C	17:31	18:31	18:48	3A	24.0	75	100	0.88	2.3	18	85		Sootblowing primary SH start time 16:33	90.00
8/13/2019	11	Operator A	20:22	21:50	22:10	3A	24.0	85	100	0.95	2.3	21	78		Sootblowing stopped	90.40
8/13/2019	12	Operator A	22:10				28.0	75	110	0.88	3.0	21	78			

12.2 Simulation Model Results

Table 6: Steam generator efficiency (S1) calculated with the simulation model according to a DoE planning

	Factors (controllable parameters)						**Response**
Experiment number	P1	P2	P4.B	P5	P6	P7	S1
1	28.0	75	0.80	2.3	21	85	83.42
2	28.0	85	0.88	3.0	21	78	82.65
3	28.0	65	0.88	3.0	21	78	80.97
4	28.0	65	0.88	1.5	21	78	82.38
5	26.0	75	0.88	2.3	21	78	83.33
6	26.0	85	0.88	2.3	23	85	83.42
7	26.0	75	0.80	1.5	21	85	84.15
8	26.0	85	0.80	2.3	23	78	83.56
9	26.0	75	0.95	1.5	21	85	83.94
10	26.0	65	0.95	2.3	18	78	81.71
11	28.0	75	0.88	3.0	18	78	82.52
12	24.0	75	0.80	2.3	21	70	83.55
13	26.0	65	0.88	2.3	23	85	81.77
14	28.0	75	0.95	2.3	21	85	83.18
15	24.0	75	0.95	2.3	21	70	83.34
16	26.0	85	0.80	2.3	18	78	83.55
17	26.0	75	0.95	3.0	21	85	82.55
18	26.0	75	0.95	1.5	21	70	83.94
19	28.0	75	0.95	2.3	21	70	83.18
20	26.0	75	0.88	2.3	21	78	83.33
21	24.0	75	0.88	1.5	18	78	84.06
22	24.0	75	0.88	3.0	18	78	82.71
23	24.0	85	0.88	1.5	21	78	84.06
24	26.0	75	0.80	3.0	21	85	82.78
25	24.0	75	0.88	3.0	23	78	82.71
26	26.0	85	0.95	2.3	18	78	83.35
27	24.0	85	0.88	3.0	21	78	82.71
28	26.0	75	0.88	2.3	21	78	83.33
29	26.0	65	0.80	2.3	18	78	81.91
30	26.0	75	0.88	2.3	21	78	83.33
31	26.0	85	0.88	2.3	18	70	83.41
32	26.0	85	0.88	2.3	18	85	83.41
33	24.0	65	0.88	1.5	21	78	83.98
34	28.0	75	0.88	1.5	23	78	83.95
35	24.0	65	0.88	3.0	21	78	82.62
36	24.0	75	0.80	2.3	21	85	83.55
37	26.0	65	0.88	2.3	18	70	81.77
38	26.0	85	0.88	2.3	23	70	83.42
39	26.0	65	0.88	2.3	23	70	81.77
40	26.0	75	0.80	3.0	21	70	82.78
41	26.0	65	0.95	2.3	23	78	81.71
42	26.0	65	0.88	2.3	18	85	81.77
43	28.0	75	0.88	1.5	18	78	83.95
44	26.0	75	0.88	2.3	21	78	83.33
45	26.0	65	0.80	2.3	23	78	81.92
46	28.0	75	0.88	3.0	23	78	82.52
47	24.0	75	0.88	1.5	23	78	84.07
48	28.0	75	0.80	2.3	21	70	83.42
49	28.0	85	0.88	1.5	21	78	84.06
50	26.0	75	0.80	1.5	21	70	84.15
51	26.0	85	0.95	2.3	23	78	83.35
52	26.0	75	0.88	2.3	21	78	83.33
53	24.0	75	0.95	2.3	21	85	83.34
54	26.0	75	0.95	3.0	21	70	82.55