

Sixth International Conference on Sensitivity Analysis of Model Output

The effect of quality and reserves uncertainty to production scheduling of a lignite mine feeding a power plant

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Abstract

The effect of uncertainty sources to the stochastic optimization of the combined project of a new surface lignite mine exploitation and power plant operation for electricity generation is investigated. Major sources of uncertainty that were considered are the reserves and the quality of the lignite. Since probability distribution functions for these uncertainties were estimated during the detailed exploration phase of the deposit, the overall goal is then to determine the optimal capacity of the power plant and consequently the optimal production rate of the mine over the time. The optimization objective that was selected is the maximization of the expected net present value of the project. Emphasis is placed on the mathematical analysis applied for the investigation of the effect of the two main parameters in project optimization.

Keywords: Type your keywords here, separated by semicolons ;

1. Stochastic model – uncertainty/sensitivity analysis-optimization

The optimization of a combined project including a lignite surface mining exploitation and a corresponding power plant operation for electricity generation, under conditions of uncertainty, constitutes a very interesting decision-making problem. The viability of the project depends on the characteristics of the mineral deposit as well as on economic, market, environmental or other parameters. New lignite surface mining scheduling with the continuous operation system developed to feed a corresponding power plant, based on the exploration results, is mainly affected by the lignite quality that presents spatial variability as well as by the lignite reserves uncertainties connected with the dynamic situation of the mining operation.

In order to investigate the effect of these two parameters uncertainty, a mathematical analysis was applied based on a stochastic optimization model that was developed, incorporating the interdependencies of the project parameters. The non-linear optimization objective function of the model, expressing the economic viability of the project, is the expected net present value of the project:

$$Z=f(P,T,H,n,N,p,c_p,c_m,c_e,\kappa,\varepsilon,\mu,v,t) \quad (1)$$

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where:

Z: net present value of project cash flow (viability index), P: capacity of power plant, T: hours of power plant operation (annually), H: lower calorific value of the lignite, η : efficiency of power plant, N: project lifetime, p: electricity selling price, c_p : power plant operating cost, c_m : mining operating cost, c_e : environmental cost of the mine & power plant, κ : time of negative cash flow for power plant construction and mine opening phase, ε : discount rate, μ : depreciation time period for mining equipment, ν : depreciation time period for power plant equipment, t: tax rate. If L is the annual lignite production of the mine, then $L=L(P,T,H,\eta)$ and $N=N(L,R)$.

The effect of uncertainty (measurement errors and variability) of R, H, η , c_p , c_m and c_e to the Z was investigated by performing a preliminary Monte Carlo uncertainty/sensitivity analysis (UA/SA). Results indicated that the contribution of quality, H, and reserves, R, to the variance of Z, is considerable higher than the contribution of the power plant efficiency, η , and cost (c_p , c_m , c_e). Since the estimated contribution of H and R to the variance of Z was ~90%, these input parameters were considered as the main sources of uncertainty in this study. Statistical analysis of lignite quality and reserves data, obtained during the exploration of the deposit, indicated that the measurement errors for H and R are small compared to their variability. Measurement errors reflect the uncertainty of individual data because of unavoidable errors in sample preparation and analysis, while variability refers to uncertainty in average estimation because of the insufficient number of initial data or non representative sampling.

The goal of the optimization is to determine the optimal capacity of the power plant, P, and consequently the optimal production rate, L, of the mine. Today, power plants are constructed at standardized capacities (discrete values) and the selection of the suitable capacity is usually based on empirical criteria and rules (e.g. Taylor's rule). However this selection is not always the optimal, especially when input factors are of uncertain nature. The developed method in this study utilizes the stochastic non-linear discrete optimization to find the optimal capacity of the power plant and consequently the optimal production rate of the mine. To increase the efficiency of the optimization process and to minimize the required time (stochastic optimization is time-consuming due to the large number of the required simulations) a set of possible solutions is first determined by using the existing empirical criteria. In this way, the search for the optimal solution is limited to a relative small number of alternatives. The objective is to maximize the 5th percentile of the net present value, $Z_{5\%}$ (net present value which we are 95% confident of achieving or exceeding).

The above methodology was applied for the determination of the optimal annual production rate to a new surface lignite mine. The lognormal probability function was found to represent the uncertainty of R and H with mean values 254 Mt and 1350 cal/g respectively, while the corresponding standard deviations were estimated to 10% of the mean values. The estimated optimal values ($P_{\text{optimal}}=700$ MW, $L_{\text{optimal}}=7.650$ Mt) are considerable lower to those obtained when uncertainty of R and H is ignored ($P_{\text{optimal}}=900$ MW, $L_{\text{optimal}}=9.613$ Mt). Finally, the optimal values were estimated assuming that the uncertainty of R and H were minimized to 5%. In practice this can be achieved by carrying out an additional exploration program to obtain more samples. The obtained new optimal values ($P_{\text{optimal}}=800$ MW, $L_{\text{optimal}}=8.636$ Mt) results in an increase of the net present value of the project by 30 M€ (6%). Comparing this profit to the cost of an additional exploration program, a rational decision about the exploration and exploitation strategy of the lignite deposit can be made.

2. References.

- Galetakis M., Vamvuka D., 2009. "Lignite quality uncertainty estimation for the assessment of CO₂ emissions", *Energy & Fuels*, 23, pp. 2103–2110.
- Galetakis M., Alevizos G., Pavloudakis F., Roumpos C. and Kavouridis C., 2005. "Prediction of the performance of on-line ash analysers used in the quality control process of a coal mining system", *Energy Sources: Part A*, 31, pp. 1127–1142.
- Roumpos C., 2005. "Optimisation of the combined project of a lignite mine exploitation and power plant operation", *Mining-Metallurgical Annals*, 1 (1), pp. 45-64.