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Selective mining of multiple-layer lignite deposits. A fuzzy approach

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ABSTRACT

In this paper the development and the application of a fuzzy expert system for the evaluation of the exploitable reserves of multiple-layer lignite deposits, mined by continuous surface methods, is presented. The exploitable reserves are determined decisively by the structure of these deposits, as well as by the limitations of the used mining systems. In practice, thin layers of lignite and interbedded waste layers are grouped under specified assumptions regarding thickness and ash content, to form the exploitable blocks. Moreover, the decision for excavating such a block is made under subjective constraints of different importance, or by using uncertain data. Advances in fuzzy inference systems (FIS) have provided a new approach to the evaluation of multiple-layer lignite deposits. FIS have the ability to handle imprecise, incomplete or linguistically ambiguous information and incorporate them into decision-making processes. In the developed FIS (Mamdani type) new linguistic variables, related to working conditions, operators' experience and production were involved. The FIS was used for the estimation of the exploitable reserves of the Southern Field lignite deposit, located in the area of Ptolemais (Greece).

1. Introduction

Lignite, accounting about 30% of the primary energy consumption and about 56% of power generation, is the most important indigenous fuel of Greece. Greece, mining 65 Mt annually, is the second lignite producer in the EU and the fourth in the world. Approximately 96% of the lignite used to supply the existing lignite-fired power plants of Greece is mined by Public Power Corporation SA (PPC). Lignite is a key strategic fuel for Greece, due to secure supply and the controllable (stable) cost and gives a competitive strength in PPC's and Greece's fuel mix. The remaining lignite reserves that are suitable for electricity generation are 3.1 billion tones (2008). The majority of these lignite deposits have a multiple-layer structure and are located in the Ptolemais–Amynteon basin, in the area of Western Macedonia, in northern Greece (Kavouridis, 2008).

For the exploitation of these deposits, the continuous surface mining method is used. Large-scale equipment (high capacity bucket-wheel excavators, conveyor belts and stackers) is selected to achieve high output rate with low cost of mined lignite per tone (Papanikolaou, Galetakis, & Foscolos, 2004). Nowadays, the Western Macedonia Lignite Centre (WMLC) has six large scale open pit mines, which handle 300 Mm^3 of material and produce 49.3 Mt of lignite (2007). The lignite deposits under exploitation cover an area of 160 km^2 including 4000 Mt of proven geological reserves and 2000 Mt of exploitable reserves under the current economical and technological criteria. It is estimated that the lignite of the Ptolemais–Amynteon basin is sufficient to supply the existing power plants for another 35 years. In 2007, lignite production from WMLC contributed 48.5% to the total energy production in Greece (Kavouridis, 2008).

The extreme splitting of lignite seams, which are separated by non-lignite layers, called partings, makes the selective mining a necessity (Fig. 1). The implementation of selective mining procedures, as well as discontinuous and/or combined mining methods, differentiates the mining technology at the WMLC from the respective technology applied in similar opencast lignite mines.

The lignite supplied by opencast mines must correspond to the quality requirements of nearby power stations shown in Table 1 (Galetakis & Kavouridis, 1998). However, the quality of the mined lignite varies significantly over time and does not always meet the power station specifications. The variations of the main quality attributes are related to the structure of the deposit, which is a multiple-seam formation with successive lignite and waste-material bands of varying thickness and chemical composition. The quality of run-of-mine lignite differs substantially from the quality of the lignite layers, due to the unavoidable mixing of thin waste layers with lignite, even though selective excavation techniques are applied (Galetakis & Kavouridis, 1998, 1999).

The observed quality fluctuations can be described as short-term, intermediate and long-term variations. While short-term and intermediate variations are usually compensated by means of homogenization, mixing techniques and appropriate short-term production scheduling, long-term variations can be compensated only by appropriate long-term mine planning. This planning

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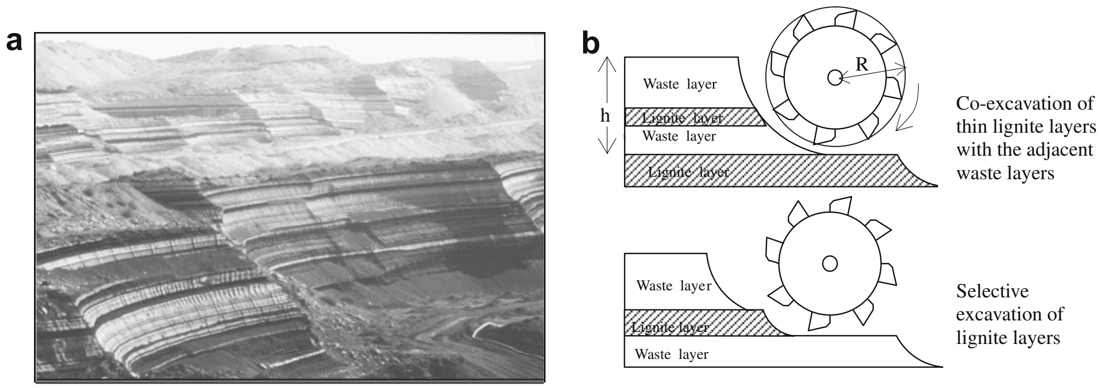

Fig. 1. (a) Multiple-layer lignite deposit. (b) Typical cases of mining using bucket-wheel excavators (terrace cutting).

Table 1
Quality characteristics of lignite used for power generation.

Power station specifications	Moisture (%)	Ash (%)		Low calorific value (cal/g)
		As received	Dry basis	
Ag. Dimitrios				
Nominal	57.2	13	30	1300
Permissible	49–62	4.5–20.4	10.5–47.7	1050–1700
Amynteon				
Nominal	55.0	18	40	1250
Permissible	48–62	6–22	13.3–51.3	1050–1450
Kardia				
Nominal	57.0	13	30	1320
Permissible	52–60	6–22	14.0–51.2	1300–2030
Ptolemaes				
Nominal	57.0	13	30	1320
Permissible	52–60	6–22	14.0–51.2	1300–2030

ensures uniform quality throughout the entire operation cycle, which may last a few decades. The first step in a planning process is the determination of the exploitable lignite, using data obtained from boreholes within the potential mining area. The determination of exploitable lignite is a computer-aided iterative procedure, where thin layers of lignite and partings are grouped under specified assumptions regarding thickness and ash content, to form the exploitable blocks. A computer model of selected deposit attributes can thus be created, by dividing the deposit into small blocks and by assigning a number of attributes or properties to each block. The developed model is the basis for all consequent planning steps. The main criteria used for the formation of the exploitable lignite blocks are:

- Minimum thickness of lignite seam and partings (waste layers) that can be excavated by selective mining. These values are mainly depended on the technical data of the excavator, the bench geometry and the type of cutting.
- Maximum ash content of the mined lignite. This value is closely related to the specifications of the power station which is fed by the mined lignite.
- Dilution and mining loss. These parameters are used in order to take into account the unavoidable co-excavation of waste layers, during the extraction of the lignite blocks.

The formation of an exploitable lignite block is shown schematically in Fig. 2. The quality of an exploitable lignite block, formed

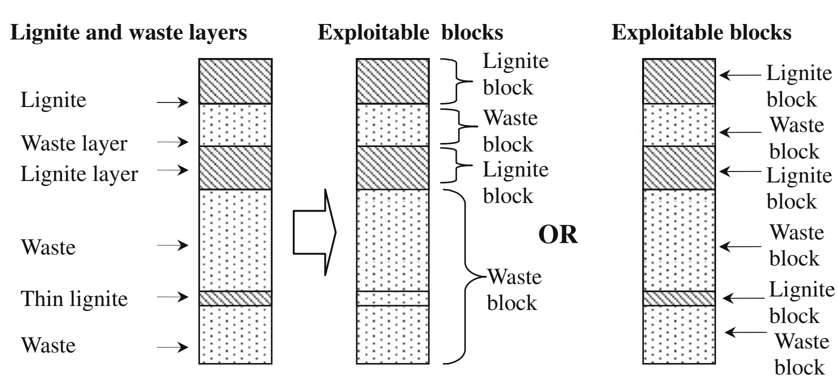

Fig. 2. Different possible approaches for grouping lignite and waste layers to form the exploitable blocks.