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SciVerse ScienceDirect
Procedia Environmental Sciences 12 (2012) 640 – 645
Procedia Environmental Sciences

Uncertainty Analysis of Coalbed Methane Economic Assessment with Montecarlo Method1

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Abstract

Uncertainty analysis of coalbed methane (CBM) economic assessment is key to weakening the high potential risks of CBM exploration. In this paper, the uncertainty analysis method of CBM projects is created with montecarlo simulation. Firstly for discovering the risk origins of CBM economy, the main uncertainty factors are analyzed and the risk transformation process model of main uncertainty factors is built. Secondly, compling with above process model, CBM economic risk analysis algorithm steps are discussed detailed. Finally, by an example, the CBM economic risk of target area is cacluated. The results show that montecarlo method is an efficient for uncertainty analysis of CBM assessment.

Keywords: MonteCarlo method; coalbed methane; economic assessment

1. Introduction

Coalbed methane (CBM) is a natural gas formed by geological, or biological, process in coal seams. Its component mainly is methane. CBM can be fully regarded as a kind of high-quality energy and chemical raw materials, and can be used as the supplement of natural gas resources. According to a recent assessment, CBM resource amount of china reaches about 37 trillion cubic meters, located on deeper than 2000 meters underground, which is equivalent to the total resource amount of natural gas in China[1]. CBM is not only an effective alternative energy sources for china, the exploration and use of it could also be helpful for avoiding coal mine accidents and reducing the methane emission. So the CBM exploration plays an important role in Chinese government plan.

However how to explore the CBM? Will an investment is profitable for the company or the governments? The answer is important to the managements. CBM economic assessment is important to the project evaluation, so choosing the index of economic assessment and building the definite steps of CBM economic assessment are significant. The research of CBM projects economic assessment in two different ways. One is the traditional way in which parameter is considered as finite. the other is an advanced way in which parameters are considered as indefinite. The traditional way is

[1] This work is supported by the National Natural Science Foundation of China (Nos. 40472146 and 40972207) and the National Science and Technology Major Projects(Nos. 2009ZX05039-004-02).

1878-0296 © 2011 Published by Elsevier B.V. Selection and/or peer-review under responsibility of National University of Singapore.
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used widely in projects economic evaluations. Dhir et al presents a rigorous procedure of reserves and economic evaluation of CBM reservoirs[2]. In this procedure, the author believes some traditional factors should be considered, such as tax credit, Gas price, drilling and complication costs, water disposal costs, operation expense and administrative expense. Luo et al have evaluated CBM development of china by Net Present Value[3]. The traditional way is not considers the distribution characters of parameters. Therefore the advanced way believes CBM economic assessment should be cosidered the disribution characters of paramters. Senthil discribed the finaicial feasibility of CBM projects using monte carlo and hypercube simulation[4].Yang has evaluated the CBM resources in key mining areas in china using montecarlo method[5]. Robertson study the economic feasibility of CO_2 sequestration in unminable coal seams in the Powder River Basin of Wyoming using probabilistic discounted cash flow[6]. However, The uncetainty origins of CBM economic assessment are many factors. The few paper discuss the origins, processes and methods of discovering the uncertainty of CBM economic assessment. In this paper, we try to model the transformation process of CBM economic assessment and put forward using montecarlo simulation to evaluate the uncertainty of the CBM economic.

Monte-Carlo method, known as a random sampling method or statistical skill test method, is used in mineral financial evaluation and engineering fields[7,8]. It's advantages over the traditional method is not only to discover the probability distribute characters but also to get the infinite value at different probability level. So it is widely used in engineering fields and the others. In the traditional coalbed methane financial evaluation method, an indefinite parameter is regarded as a constant, In fact, which is a random sampling observation of the parameter. Monte-Carlo method can overcome the problem of seeing indefinite parameters as constants during the process of estimating CBM financial evaluation.

This article is focus at introducing the main algorithm and the realization of economic assessment functions of the coalbed methane projects by Monte-Carlo method, including selection of parameters, determination of distribution function, generation of pseudo-random numbers, and evaluation of the parameters corresponding to pseudo-random numbers.

2. Main Uncertainty Factors and Risk Transformation Process of CBM Economic Assessment

Coalbed methane economic assessment is a systems engineering involving geological condition, drilling engineering, mining technology, economic circumstances and so on[9]. However CBM project risk soruces and transformation can be divided four stages on the whole. The firsts one is geological resources which is an important parameters effected by some unstable spatial parameters including coal thickness, coal area,coal density. The second one is recoverable resources which effected by coal reservior parameters including gas content, permeability, gas saturation, reservior pressure, reservoir temperture and so on. The gas content varied in different condition of embedded depth, coal rank and the complex degree of coal seam structure. The permeability is changed with the nature fracture development level of coal seam. The third one is Engineering construction which includes surface construction, gasline network, well construction. The fourth one is economical stage which includes tax, gas price, oncost, benchmark yield. The process is as the following Fig. 1.

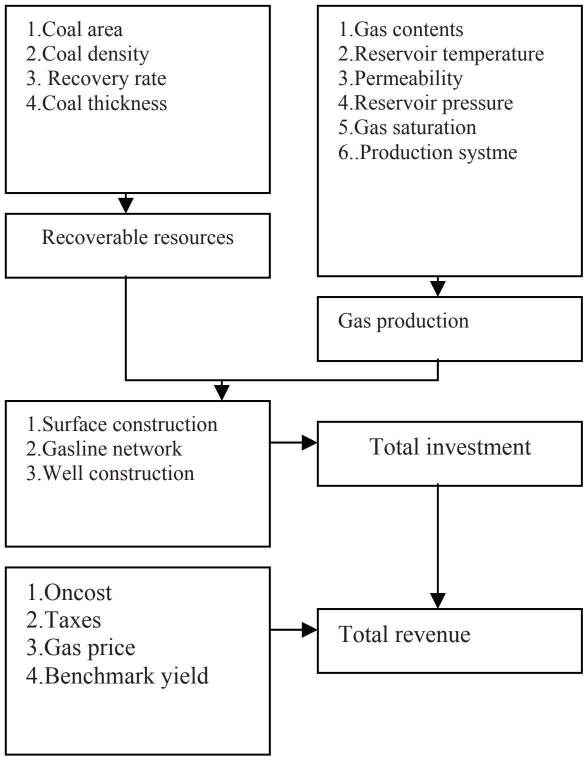

Fig.1 The risk transformation process of CBM economic assessment

3. Risk Analysis Algorthm Realization of CBM with Montecarlo Method

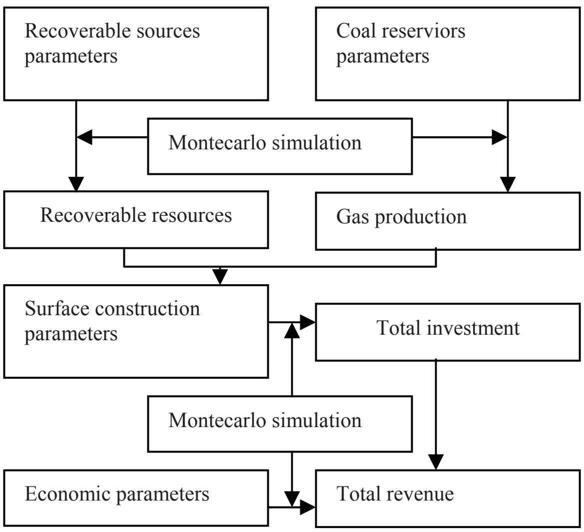

Fig 2 The steps of risk analysis algorithm

Risk analysis is a method that determines the most outcome of a decision and presents the results as a probability distribution. Complied with the risk transformation process of CBM economic assessment, the risk analysis algorithm steps are as the following Fig 2.

There are four steps in risk analysis with Monte Carlo method. The first is defining the model. The second is identifying variables and specifying their possible value with probability distribution. Third step is analysis model with Monte Carlo method. the fourth is making a decision based on the analysis results. The major steps of the algorithm realization of Monte Carlo algorithm for CBM economic assessment is as following[10]:

(a) Selecting simulation parameter, then confirming the selected index parameter is of uncertainty or not. If the selected parameter is uncertainty parameter, the calculation steps should be by the following steps.

(b)Inputting original variables' data X_i, for example production, gas price, coal seam permeability and others relevant uncertainty parameters of CBM economic assessment.

(c) Calculating the initial endpoint value, termination endpoint value, the numbers of counting interval, and expression constants of each parameter. The initial value and termination value of each calculated parameter of CBM economy assessment, respectively, correspond to the minimum and maximum of the parameter, and the numbers of statistic interval are determined at equal interval according tothe measured parameters of CBM economy assessment.

(d) Calculating cumulative frequency distribution of X, as a probability distribution function, for simulating parameter distribution of CBM economy assessment.

(e) Generating pseudo-random number R_K.

(f) Calculating X_K corresponding to R_K and calculating parameter value of CBM resources corresponding to the random number R_K.

(g) Reordering dual value (R_K, X_K) in accordance with the order from large to small of R_K, deleting the same R_K and repeat dual value (R_K, X_K), and calculating the parameter values of CBM resources in the different probability by linear interpolation.

(h)Calculating the final result of CBM economic assessmen by repeating above steps(a)-(h).

4. Uncertainty Analysis of CBM Economic Assessment in Target Area

There are two main minable coal seams(3#,15#) in target area. 3# and 15# coalseams are belong to the Permian and Carboniferous system. The gas content of 3# is between 5.88m^3/t and 32m^3/t ,while 15# coalseam is between 7.08m^3/t and 37.23m^3/t. The well test pressure is between 0.96 Mpa and 2.93 Mpa, and the pressure gradient is between 0.28 and 0.593 Mpa/100m. the Langmuir volume between 39.94 m^3/t and 46.38 m^3/t, the Langmuir pressure is between 2.69 Mpa and 3.22Mpa. adsorption time is between 2.08 day and 12.96 day.Comply with above parameters, the production effects are simulate by CMG(coalbed methane simulation software). The results is showing at Table I.

TABLE I
CBM PRODUCTION EFFECTS FROM DEFFERENT PAPRAMTERS

SimulationParameters	Value Scope	Funciton
Permeability(x_1) (md)	1.0-9.0	Y_1=286.0.3X_1+192.56
Pressure(x_2) (Mpa)	3.0-5.0	Y_2=192.5X_2-245.46
Gas content(x_3) (m^3/t)	14.0-30.0	$Y_3=49.135e^{0.0613x3}$
AdsorptionTime(x_4)(day)	3-11	Y_4=7.5046ln(x_4)+146.13

In Table I, Y_1, Y_2, Y_3 and Y_4 are Net Present Value (10^{4}yuan) .In simulation process, the prodution year is setted fifteen years, Annual percentage yield is setted 10%, and the price of gas is one yuan.

The risk form economic parameters is an important parts. However ,China coalbed methane exploration economic data is diffcult to get for its short time exploration. for overcoming above problem ,the economical data of warrior is used by numerical value transform because of the geological condition similarity between Warrior and target area.(see Table II).

TABLE II
RESERVIOR CONDITION COMPARISION BETWEEN BLACKWARRIOR AND TARGET AREA

Research area	Depth (m)	Coalthick-ness(m)	Gascontent m^3/t	Permeability (mD)	Pressure gradient (MPa/100m)
Target area	122-695	5.1-7.2 3-6.7	5.9-32 7-37	0.01-41.1	0.15-0.6
BlackWarrior	500-1201	4.6-7.6 5-15	10--17	1--25	0.88-0.95

Table II shows Panzhuang is of advantage of development compared with blackwarrior. So we consider the parameter distribution characters of the warrior can be used to panzhuang. There are plots of data from a long histry blackwarrior CBM exploration to meet the needs of large sample of Montecarlo method. By data transformation, the price probability at different points are calucated as Table III, and cost probability at different points are calucated as Table IV.

TABLE III
COALBED METHANE PRICE PROBABILITY OF TARGET AREA

Item	I	II	III
Data (yuan/10^4m^3)	10000	11000 (+10%)	12000 (+20%)
Properbility	Pg1 = 0.489	Pg2 = 0.315	Pg3 = 0.157

TABLE IV
COALBED METHANE OPERATION COST OF TARGET AREA

Item	I	II	III
Data(yuan/m^3)	0.201	0.221(+10%)	0.181(-10%)
Probability	Pr1=0.398	Pr2=0.364	Pr3=0.442

Therefore the probability combination of CBM economic parameters is as Table V.

TABLE V
COALBED METHANE ECONOMIC PARAMETERS PROBABILITY COMBINATION

number	Compstatus	probability	FIRR	FNPV（10^4yuan）
1	Pg1∩Pr3	0.173	32%	7485
2	Pg1∩Pr1	0.161	31%	7302
3	Pg1∩Pr2	0.195	30%	7119
4	Pg2∩Pr3	0.111	38%	8339
5	Pg2∩Pr1	0.104	37%	8216
6	Pg2∩Pr2	0.126	36%	8033
7	Pg3∩Pr3	0.056	44%	9313
8	Pg3∩Pr1	0.052	43%	9130
9	Pg3∩Pr2	0.063	42%	8947

From Table V, we can get that the expected value of FNPV in fifteen year is 8192.329,the standard deviation of FNPV is 963.658. and the coefficient of variation of FNPV is 0.1176. In addition about Financial Internal Rate of Return(FIRR), the expected value of FIRR in fifteen years 36.24%, the standard deviation of FIRR in fifteen years 0.03815, and the coefficient of variation of FIRR is 0.1052. Therefore the risk of target area from finaical parameters is little.

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