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Abstract: This paper established a system dynamics model of energy saving and emission reduction in coal mining area, as well as conducted simulation of different development plans, based on the analysis of energy saving and emission reduction factor of coal production links, of the complex structure of energy saving and emission reduction system in coal mining area, and of the dynamic feed-back mechanism inside the system. Result shows that total investment, coal production investment, environmental protection investment and coal energy consumptions per ton play an important part in the energy saving and emission reduction system in coal mining area. By adding total investment and refining the proportion between coal production investment and environmental protection investment, as well as reducing coal energy consumptions per ton, harmonious development of economic and energy saving and emission reduction could be achieved.

Keywords: system dynamics model; simulation; adjustment; energy saving and emission reduction; coal mining area

1. INTRODUCTION

In the process of coal production, great amount energy, such as coal, electricity, oil, etc, would be consumed, generating large amount "three wastes" pollutant (waste water, waste gas, and waste residue). In 2009, energy consumption of 71.708 million tons of standard in coal China's coal mining industry, which ranked No. 7 in 42 industries, "Three wastes" emissions of 918.185 million tons, seventh in the same [1]. Coal industry has been identified as one of the nine high energy consumption and high emission industries. Therefore, energy saving and emission reduction has become a difficult problem in China in recent years.

At present, there are many papers about energy saving and emission reduction of coal industry[2-7]. These researches focus on introducing a technology or the evaluation of the effects of energy saving and emission reduction, but not analyzing the influential elements of energy saving and pollution discharge of coal mining area. Coal mining area is a typical complex system, in which energy consumption and pollution emissions are produced from each link of coal mining, processing, transportation, and using, and are influenced by many factors, such as coal production quantity, mining investment, pollution control and comprehensive utilization, so that present a complicated law of motion. System dynamics which was proposed by Professor J. W. Forrester in the 1950s specializes in dealing with time-varying nonlinear feedback structure of complex systems. Sun established dynamic simulation model on coal resources development system based on system dynamics, Scenario analysis and policy experiment were carried out on certain mining area by setting up 3 scenarios[8]. A system dynamics model for the coal city was built on the analysis of its structure by Yao et.al and the typical coal city of Jixi was taken as an example to simulate five future development patterns[9]. Wang established regional circular economy system SD model according to the system's circular relationship, and chose three kinds of typical patterns of economic development for the simulation experiment[10]. Practice proves that system dynamics is especially suitable for dealing with complex time-varying system with high order time, nonlinear,

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multiple feedbacks, which is the large complicated system "laboratory" of social, economic and ecological.

This paper built a coal mining energy saving system dynamics model to simulate the typical mine area. Through the regulation related parameters, the economy development, energy consumption and pollution discharge of coal mining area under different development plan were simulated to provide decision-making basis for development strategic and the way of energy saving and emission reduction of coal mining area.

2. SYSTEM DYNAMIC MODEL OF ENERGY SAVING AND EMISSION REDUCTION

2.1 The system structure of coal mining area energy saving and emission reduction system

In this paper, coal mining area energy saving and emission reduction system only concerns coal energy consumption and environmental pollution caused by coal production, namely studying the relationship among coal production, energy consumption and environmental pollution. Therefore, the coal mining area energy saving and emission reduction system is composed of resource development subsystem, energy consumption subsystem and pollution emissions subsystem.

Resource development subsystem is mainly concerned about the influence of coal production investment, difficult exploitation and environmental pollution on coal production. Energy consumption subsystem takes into account material consumption, electricity consumption and coal consumption which are the three major energy consumptions in coal mining area. It discusses the relationship between three kinds of energy consumption and coal output.Pollutant emission subsystem focus on quantity generated and quantity controlled of waste water pollution, solid waste, SO2, smoke dust, stive, as well as the impact of environmental pollution caused by pollutants emission in the process of coal production.

2.2 The causality diagram and flow diagram of energy saving and emission reduction system

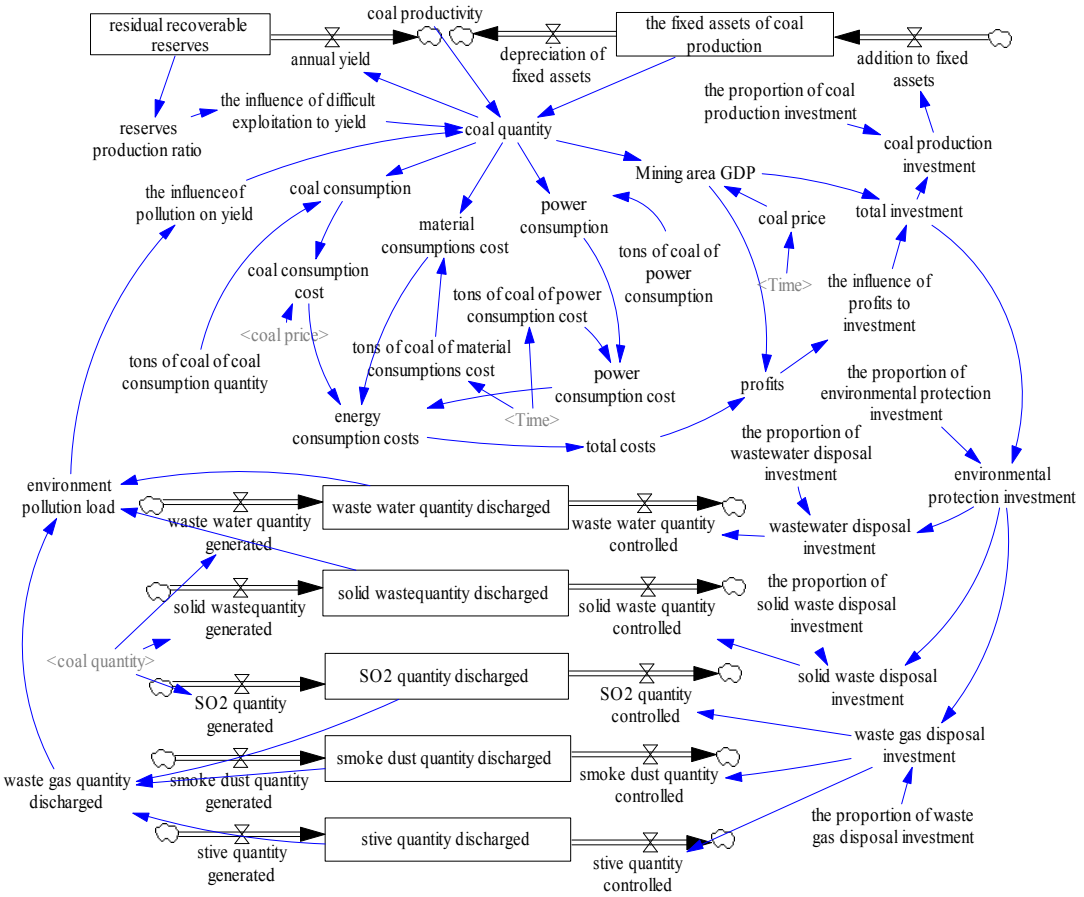


Figure1. The flow diagram of coal mining energy saving and emission reduction system

Based on the system structure and the relationship of the sub-system above, and deep analysis of the object system, the main feedback loops of coal mining energy saving and emission reduction system are obtained. According to the feedback loops, the causality diagram is transformed into the flow diagram, see Figure 1.

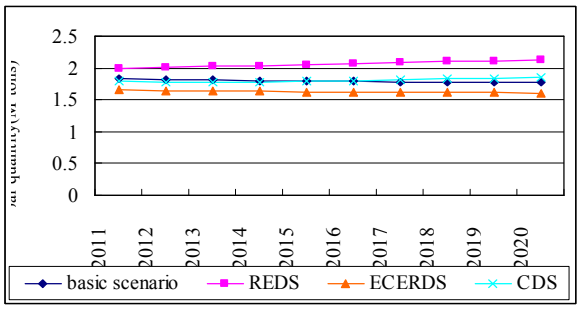
3. SIMULATION ANALYSIS

We conduct simulation analysis taking a typical coal mining area as an example with the simulation time for 2011-2015 and the simulation step for one year. Because the statistic data isn't fully, the historical data mainly relate to 2005-2010, the model parameters are determined mainly through the arithmetic average method and the regression coefficient.

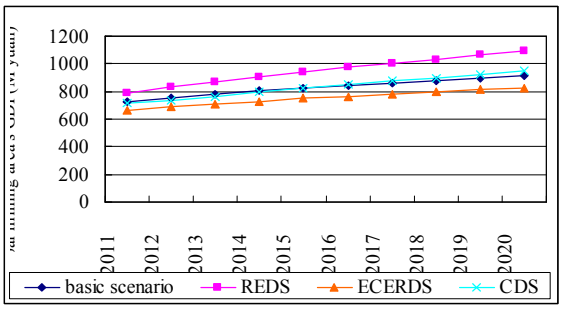
Table 1. The key system parameters of all kinds of development scenarios of coal mining area

scenarios / parameters	basic scenario	REDS	ECERDS	CDS
The coefficient of total investment	0.1	0.115	0.11	0.117
The proportion of coal production investment	0.85	0.88	0.8	0.82
The proportion of environmental protection investment	0.15	0.12	0.2	0.18
The coal consumption amount per ton coal	0.0045	0.00465	0.0025	0.0035
The material consumption cost per ton coal	45	47.25	42.75	43.5
The power consumption amount per ton coal	31	33.5	27.5	29.5
The proportion of waste water disposal investment	0.4	0.38	0.37	0.4
The proportion of solid waste disposal investment	0.06	0.08	0.15	0.08
The proportion of waster gas disposal investment	0.54	0.54	0.48	0.52

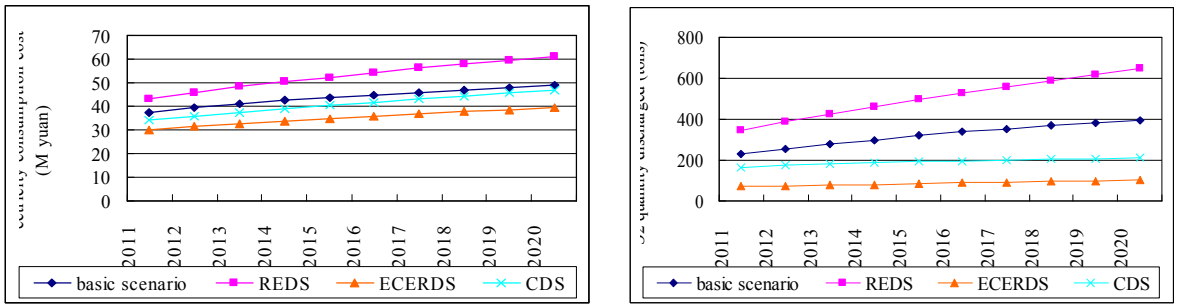
After the model test, the model is run. Then, three kinds of development scenarios of coal mining area, namely, the rapid economic development scenario (REDS), energy conservation and emission reduction development scenario (ECERDS) and the coordination of economy and energy conservation and emission reduction development scenario (CDS), are designed by changing the key parameters of the model, and the simulations are conducted to get all kinds of scenarios of mining area economic development, energy consumption and pollution emission. The key system parameters of basic scenario and the above three kinds of scenarios are shown in table1.



（a）coal production



（b）coal production



（c） electricity consumption （d） SO2 emission

Figure2. System dynamics simulation results of different parameters

Figure2(a) and (b) show that raw coal quantity and total product in coal mining area are the highest in REDS, followed by CDS, and the lowest in ECERDS. Figure2.(c) and (d) show the comparison of electricity consumption and SO2 emission. Because of the limited space, the figures of coal consumption, material consumption, waste water emission, solid waste emission, smoke dust emission and stive emission are left out. The consumption cost of three kinds of energy and the emission of five contaminations in REDS is far larger than that of the other three scenarios, while that of ECERDS is much less than the other three. Electronic consumption and material consumption cost of CDS is much lower than the current system and coal consumption and emission of five contamination is much less than that of the current system. (note: the emission quantity refers to accumulated one) .

Through the analysis above, REDS has the fastest economic growth and the largest production in coal mining areas but it also has high energy consumption and emission. Its rapid economic growth is at the expense of excessive exploration, high energy consumption and high emission. Under the circumstances of sustainable development, energy conservation and emission control, the economic growth is no longer the only initial goal for development because if so, more money needed to tackle with the contamination and to resume the ecosystem. Resource mining enterprises has a relatively short length of service. But rapid economic growth of such short service year does not mean a long-term economic effect, because resuming the ecosystem needs a rather long time and huge expense. Thus, REDS is a cautious choice and needs more consideration for REDS to make.

Under the guarantee of the economic development of the mining area, CDS effectively reduce the energy consumption and pollution emission. Although the single indexes of economy, energy saving and emission reduction are not the best ones, from a long-term perspective, the economy grows while the pressure of ecosystem reduces and the confining effects that environment has on mining also relatively decreases, which shows compared with other scenarios of development, CDS has a more promising future.

4. CONCLUSION

We can achieve the harmonious development of economy and energy saving and emission reduction through the following aspects.

4.1 Adjust the overall development strategy

We can take energy saving and emission reduction into account when making the overall mining development strategy. We should also change our concepts and adjust our strategy planning to make sure that the key measure to development is a way with low energy consumption, low emission, less contamination and high efficiency.

4.2 Increase the investment and properly improve the proportion of environmental protection investment

We need to increase the investment in mining areas in order to popularize the application of new tech, new process and new material and meanwhile use new high efficient, energy saving and environmental friendly equipment to replace the old ones with high consumption. In addition, we should properly improve the proportion of environmental protection investment, take the comprehensive utilization technology of mining resource and largely curb the "three wastes".

4.3 Reduce the unit energy consumption

From the energy consumption structure, the cost of material consumption is the largest that of electronic comes next and the lowest one is coal consumption. During the coal making process, wooden and steel material will be consumed most. Thus, we can improve mining method and under working support patterns, improve the repetitive use ratio to reduce the use of wooden and steel and to reduce the coal consumption. Besides the material, electronic and coal are the main energy consumptions. Among these energy consumptions electronic consumption is the highest and thus it has the most potential to save energy. We can introduce new tech, reform the air compressor, draining pump, transportation facility, ventilation device, equipment for excavation, hoisting equipment and other equipment of high consumption to reduce the coal's electricity consumption. Additionally, we can adopt high efficient and clean energy conservation boiler or other thermal energy equipment to substitute such equipment as boiler in order to reduce coal consumption.

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