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MATHEMATICAL MODEL OF THE DISTRIBUTION OF ELECTRICITY BETWEEN REGIONS WITH MINIMIZING COSTS

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ РАСПРЕДЕЛЕНИЯ ЭЛЕКТРОЭНЕРГИИ МЕЖДУ РЕГИОНАМИ С МИНИМИЗАЦИЕЙ ЗАТРАТ

Kozlov A.D. / Козлов А.Д.
student / студент
Sorokin V.A. / Сорокин В.А.
student / студент
Saint Petersburg State University, Saint Petersburg, Universitetskaya naberezhnaya 7–9, 199034
Санкт-Петербургский государственный университет, Санкт-Петербург, Университетская набережная 7–9 34, 199034

Abstract. *In this article, we consider the distribution of electricity that a power plant produces between adjacent regions. In other words, the network, the nodes of which are areas between which it is necessary to distribute the electricity coming from its source. Complicating the task is the fact that the needs of the regions change every period, and the size of the storage is limited. In addition, transportation costs also change every period.*

Using the methods of the theory of dynamic programming, we have found the best methods for distributing electricity so as to minimize the cost of transportation to the consumer.

Keywords: *electricity, network, energy, dynamic programming, optimal distribution, profit maximization, cost minimization.*

Introduction.

As you know, any power plant produces electricity by converting natural energy. Those. Hydroelectric power plants produce electricity from the mechanical energy of the moving water - rivers, reservoirs, etc. Thermal power plants due to the conversion of chemical energy. A nuclear power plant operates at the expense of a nuclear reactor, a device designed to organize a controlled self-sustaining chain reaction of the fission of heavy elements, which is always accompanied by the release of energy. Wind power plants generate electricity from wind energy. Solar power - from the energy of solar radiation.

Any power plants are complex economic systems that always unite simple concepts - the need to supply the power plant with a major resource for power generation and the need to market the electricity produced. Resource for thermal power plants and nuclear power plants - the fuel that costs money. The resource for hydroelectric power plants is water, for the accumulation of which an artificial reservoir is usually used.

Design, construction, and maintenance of hydroelectric power are also reduced to costs in the form of money. These power plants are usually very large, large, of federal significance and, accordingly, produce a lot of electricity, which must be delivered to electricity consumers and distributed between them. The main task of such power plants is the supply of electricity to the regions of the country. The location of the power plant is chosen to take into account economic and geographical convenience. Consumers are selected on the basis of the power generated by the power plant and the region’s electricity needs.

To increase efficiency and, therefore, maximize the profit of such power plants, the only way to minimize the cost of electricity generation. Wind and solar power plants are currently not traditional, alternative sources of electricity. Resource for their needs - wind energy or sunlight. Such resources are not limited, but their use causes many difficulties - solar panels and wind generators are expensive and require special maintenance, therefore such power plants are local sources of electricity. On the other hand, these power plants, in fact, being private enterprises can compete with the main electricity suppliers in the private sector, for example, in suburban settlements or for individual industrial enterprises.

To maximize the profit of such power plants, both the cost of electricity production and the cost of sale are important. Also, they have to face the phenomenon of corruption, since they are competitors for monopolists.

Depending on the remoteness of the power station to the consumer, another problem arises - the loss of power transmission. These problems are associated with physical phenomena that occur when an electric current flows in a conductor. Therefore, when transmitting electricity over long distances, the voltage is first repeatedly increased (by the same amount by decreasing the current) using step-up transformers, and then, near the consumer, is lowered using step-down transformers. This can significantly reduce the loss in transmission of the same electrical power. However, as the voltage rises, various other physical phenomena that cause losses begin to occur, which are not considered in this work.

Main part.

We formulate the initial conditions: There is one power plant, the storage capacity of the primary resource is limited, we denote it - S. There are two consumers of electricity, it is necessary to supply electricity to both regions. We consider 6 periods of time for the production and sale of electricity, the cost of electricity production is known in the i-th period of time, we denote it by π, we know the electricity needs of the regions in the i-th time period, we denote them by $d1_i$ and $d2_i$.

The purpose of studying the model is to maximize profits, taking into account the source data.

In order for a power plant to fulfill its electricity supply plan, the purchasing department must supply a primary resource at the beginning of each time period. The price of electricity production is $p_i, i = \overline{1,6}$ and the need of the regions $d_i = d1_i + d2_i, i = \overline{1,6}$ equal to the sum of the needs of each region are indicated in the table. The storage capacity of the primary resource is limited and should not exceed S.

We introduce the notation:

s_i is the number of primary resources in the accumulator during the period of time i before buying ai.

a_i is the volume of purchases of primary resources in time period i.

x_i is the balance of the primary resources in the accumulator in the period of time i after the purchase a_i.

$F_i(x)$, $G_i(y)$, $H_i(z)$ showing how much money (the balance of the main plus income) we will have at the end of the i-th stage, having invested at the beginning of this stage the amount of funds x in the first industry and y in the second and z in the third.

We construct a scheme for solving this problem using dynamic programming. The criterion is the sum of all funds remaining in both industries after the m-stage, plus the income is given by both sectors at this stage. The criterion in question is a special case of an additive criterion: it is all acquired at the last stage, i.e. $W = w_m$, and at all previous stages of its increment w_i are equal to zero.

1. Fix outcome $(m-1)$-step (preserved funds plus income) Z_{m-1}. Conditional optimal control $x^*(Z_{m-1})$ - at which there will be a maximum amount of funds (fixed assets plus income) after m-step

$$w(Z_{m-1}) = Z_m(Z_{m-1}). \tag{1}$$

But, given formulas above, you can write

$$w_m = F_m(x_m) + G_m(y_m) + H_m(z_{m-1} - x_m - y_m). \tag{2}$$

Conditional optimal control on m-step $x_m^*(Z_{m-1})$ can be found from the condition

$$W_m^*(Z_{m-1}) = \max_{\substack{0 \le x_m \le Z_{m-1} \\ 0 \le y_m \le Z_{m-1}}} (F_m(x_m) + G_m(y_m) + H_m(Z_{m-1} - x_m - y_m)). \tag{3}$$

2. Fix initial $(m-2)$-step Z_{m-2}. Conditional optimal control $x_{m-1}^*(Z_{m-2})$ can be found from the condition

$$W_{m-1,m}^*(Z_{m-2}) = \max_{\substack{0 \le x_m \le Z_{m-1} \\ 0 \le y_m \le Z_{m-1}}} \{W_m^*(F_{m-1}(x_{m-1}) + G_{m-1}(y_{m-1}) + \\ + H_{m-1}(Z_{m-1} - y_{m-1} - z_{m-1}))\tag{4}$$

etc.

3. Fix Z_{i-1}. Conditional optimal control $x_i^*(Z_{i-1})$ can be found from the condition

$$W^*_{i,i+1,\dots,m}(Z_{i-1}) = \max_{0\le x_i\le Z_{i-1}} \{W^*_{i+1,\dots,m}(F_i(x_i) + G_i(Z_{i-1} - x_i))\} \quad (5)$$

etc.

4. The optimal control at the first step x and the maximum value of the gain y is found from the condition

$$W^* = W^*_{1,2,\dots,m} = \max_{0\le x_i\le Z_0} \{W^*_{2,\dots,m}(F_1(x_1) + G_1(y_1) + H_1(Z_0 - y_1)\}. \quad (6)$$

5. The outcome of the first step with optimal control:

$$Z_1^* = F_1(x_1^*) + G_1(y_1^*) + H_1(Z_0 - y_1^*). \quad (7)$$

Optimal control in the second step:

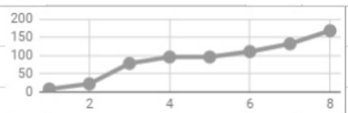
$$x_2^* = x_2^*(Z_1^*). \quad (8)$$

The outcome of the second step with optimal control:

$$Z_2^* = F_2(x_2^*) + G_2(y_2^*) + H_2(Z_1 - y_2^*) \quad (9)$$

and so on until the last step.
The result of the work is shown in the table:

Initial storage capacity	0
Maximum storage capacity	40



Period		1 region		1 region		1 region		The price of the production unit of electricity	Markup, %	Production cost	Selling price		Income	Profit
		Need, MW	Expenses, %	Need, MW	Expenses, %	Need, MW	Expenses, %							
1	First quarter 2008	20	10	15	10	10	10	5	15	200	207	Sale in any region	7	7
2	Second quarter 2008	20	10	20	15	20	20	7	20	280	294	Sale in the 1 and the 2 region	14	21
3	Third quarter 2008	30	1	20	20	20	20	10	20	300	356,4	Sale in the 1 region	56,4	77,4
4	Fourth quarter 2008	30	1	30	2	30	3	12	5	480	497,7	Sale in 1 and the 2 region	17,7	95,1
5	First quarter 2009	10	7	20	8	15	7	11	7	0	0	Do not sell	0	95,1
6	Second quarter 2009	40	7	40	6	40	7	11	10	440	454,96	Sale in the 2 region	14,96	110,06
7	Third quarter 2009	15	7	20	8	20	10	13	13	520	541,3265	Sale in any region	21,3265	131,3865
8	Fourth quarter 2009	0	10	35	9	20	10	10	20	400	436,2	Sale in the 2 and the 3 region	36,2	167,5865

(tabl.1)

Conclusions.

Thus, as a result of the work done to study the methods of distribution of electricity between regions, we came to the conclusion that in certain problems one can get a quick optimal solution through intuitive reasoning. But in the case of consideration of more voluminous problems, the formalization of mathematical models and finding optimal policies using dynamic programming can significantly simplify calculations and lead to cost minimization and profit maximization.

The method of dynamic programming is not always the easiest approach but can be used as an apparatus for solving various tasks.

References:

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Abstract. *В этой статье мы рассматриваем распределение электроэнергии, которую производит электростанция между близ лежащими регионами. Иначе говоря сеть, узлами которой являются области, между которыми необходимо распределять электроэнергию, поступающую от ее источника. Осложняет задачу тот факт, что потребности регионов меняются каждый период, а размеры хранилища ограничены. Кроме того каждый период меняются также и затраты на транспортировку.*

Используя методы теории динамического программирования мы нашли оптимальные методы распределения электроэнергии так, чтобы минимизировать затраты на транспортировку к потребителю.

Keywords: *электричество, сеть, энергия, динамическое программирование, оптимальное распределение, максимизация прибыли, минимизация затрат.*

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