CHOOSING OF ENERGY SYSTEM DEVELOPMENT STRATEGY BY APPLYING "GAME THEORY"

K.Ramazanov
e-mail: r.kerim@gmail.com

N.Ramazanov
e-mail : r.nazir@rambler.ru

Institute of Physics, Azerbaijan National Academy of Sciences, Javid av. 33, AZ-1143, Baku, Azerbaijan

Ahmet Nayir
e-mail: *a_nayir@yahoo.com*
Department of Engineering, Halic University, Buyukdere Cad. 101, 34394, Istanbul,Turkey

A.Salimova
Azerbaijan Scientific Research and Project Investigation Engineering Institute,
Zardabi av.94,AZ-1012, Baku, Azerbaijan

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ABSTRACT

Choosing of optimal variant for energy system development is the most technical and economic problem. Generally the information used for choosing optimal strategy is not determinate. The information either probable or in interval that means it is ambiguity.

In order to choose energy system best strategy in vagueness it's recommended to do it based on "Game Theory".

I. INTRODUCTION

Energy system of Azerbaijan Republic could provide energy demand of the country for this moment. Energy demand of the country is 23-24 billion kWh.

Total installed capacity of power plants is approximately 5390 MW, but active power in wintertime period is 3470 MW. Deficit power in wintertime period is purchasing from Russia.

Most parts of generation capacities used in energy system are physically and morally out of date.

Due to reasons shown above energy system of Azerbaijan couldn't provide increased energy demand. It has been forecasted that energy demand will be 28-30 billion KWh in nearest 7-10 years.

In order to provide energy demand with minimum costs in minimum time many development strategies have been prepared.

In order to make the best choice among them it's suggested to use the "Game Theory".

It's suggested to use methods based on principals of "Game with Nature" theory to choose optimal development program for energy system.

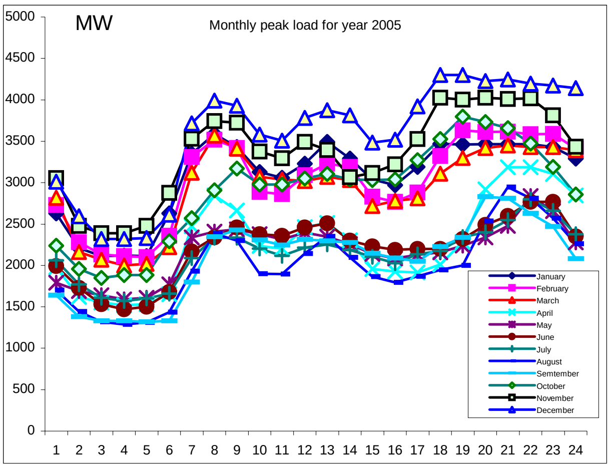
Principally power supply system of Azerbaijan Republic could provide its own energy demand.

Power system has connections with Russia, Iran and Georgia. The system is trying to work more efficient by using these connections.

The following problems are seriously impact to power system activities:

- More than 75% of generation capacity (Ali-Bayramli TPP- 1050 MW, AzDRES – 2400 MW) became out of date. Because of that the fuel consumption increases.
- Transmission lines of power supply system and equipment of power distributing network also became out of date. That's why there is energy tripping and the technical losses above the line.
- The problems still spring up in power system. Energy demand of consumer is still growing up. Unfortunately this growth is different during day period. If in wintertime evening (19:00 –23:00) period the required power from energy system is about 4000 MW, then at night (1:00 – 6:00) this figure becomes 2000 – 2100 MW. During daytime average power demand is 2700 – 3000 MW.

Even if in summertime the total demand decreases up to 35-40%, the difference between night peaks and day minimums are still the same (Figure 1).



It is possible to analyze energy system annual loads changing during seasons according to monthly peak loads for 2005 shown in figure 1. The main reason of analyzes is to improve economic mechanism for regulating energy system load graphs and to define the potential possibility of advantages afterward regulating. This value of potential advantage characterizes the reducing of energy system peak loads in maximum and transferring in minimum. In order to make it simple it's important to show peak loads changing during seasons of year 2005 in 3D frame. (Figure 2)

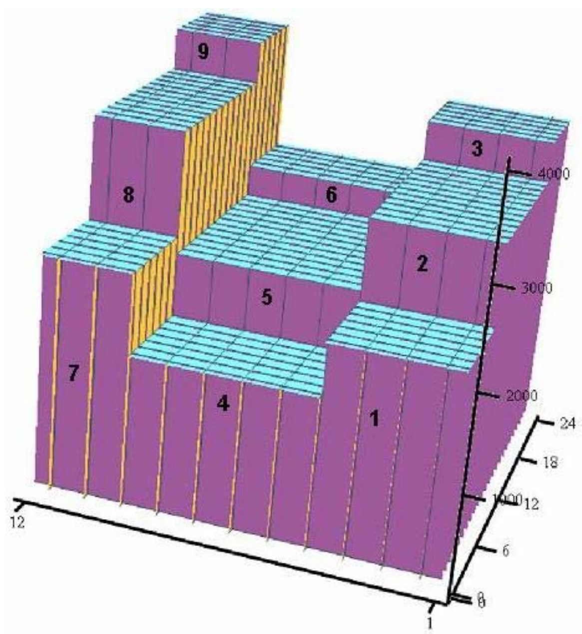


Figure 2

1. 6 hours nighttime minimum in January-April
2. 12 hours daytime in January-April
3. 6 hours evening time peak in January-April
4. 6 hours nighttime minimum in May-September
5. 12 hours daytime in May-September
6. 6 hours evening time peak in May-September
7. 6 hours nighttime minimum in October-December
8. 12 hours daytime in October-December
9. 6 hours evening time peak in October-December

Here 3D frame in figure 2 prepared with special algorithm based on year 2005 load graphs. It's possible to reduce peak load demand by providing optimal arrangement of loads during seasons and daily hours. It's also possible to show this reduction as one of energy system development strategies. It is also possible to include this strategy into Payment Matrix as one of its elements.

It gives a chance to use proper tariff, which changes 3 times (normal, peak hours and nighttime load minimum) within a day in load graphs arrangement.

Even if Azerbaijan energy system could provide its own consumption, because of mentioned factors above the problems in energy providing could be in nearest future.

In order to solve the problems in time that might be in energy supply, the new power plants are being built up, transmission lines are being repaired and reconstruction works are being made in energy supply network.

It's planning to make some procedures in order to improve the efficiency of power industry investments and to optimize the energy system regime parameters.

It is more important to estimate the efficiency of planning actions, to compare the possible development directions (strategies), to calculate the expected risks and to make a decision at the end.

Due to ambiguity source information used for making a decision, existence of probabilistic values of some indicators (costs, generation capacities, etc) and multitude possibility of strategies in energy development needs to apply mathematic methods to solve the problem.

To compare strategies of energy sector development and to minimize the risks in this case its perspective to use “Game Theory”.

More appropriate mathematic method could be “Game with Nature” theory, one of directions of “Game Theory”.

As is well known “Game Theory” devoted to find the mathematic solutions between players with different interests (generally its conflict interests) [1,2].

The main character of “Game with Nature” theory is that the nature as a player in game doesn't try to win. The nature could only create different situations. In these situations the decision player (the player who makes the decisions) should make an adequate decisions. The decision player (DP) can choose several strategies for each situation created by nature. The main point of this sum is to find a decision with minimum risk against each situations created by nature.

The game algorithm between DP of energy sector development and nature could be as the following: the strategy of DP “j” against the strategy given by nature “i”. In this case we can present costs as “3ij”. DP's strategy Y_j(j=1÷m) against the strategy given by nature X_i (i=1÷n). In this case DP's matrix "Payment Matrix" that shows all costs could be as table 1.

Y / X	Payment Matrix						Characteristic values			
	DP's strategies						Z_i^{max}	Z_i^{min}	$\overline{Z_i}$	R_i^{max}
	Y_1	Y_2	.	Y_5	.	Y_m				
X_1	Z_{11}	Z_{12}	.	Z_{15}	.	Z_{1m}	Z_1^{max}	Z_1^{min}	$\overline{Z_1}$	R_1^{max}
X_2	Z_{21}	Z_{22}	.	Z_{25}	.	Z_{2m}	Z_2^{max}	Z_2^{min}	$\overline{Z_2}$	R_2^{max}
.	.	.	.	.	.	.	.	.	.	.
X_5	Z_{51}	Z_{52}	.	Z_{55}	.	Z_{5m}	Z_5^{max}	Z_5^{min}	$\overline{Z_5}$	R_5^{max}
.	.	.	.	.	.	.	.	.		.
X_n	Z_{n1}	Z_{n2}	.	Z_{n5}	.	Z_{nm}	Z_n^{max}	Z_n^{min}	$\overline{Z_n}$	R_n^{max}

Here Z_{ji} – the value DP's costs "j" strategy against "i" strategy of nature. Z_i^{max} –DP's maximum costs appropriate to "i" strategy of nature. Z_i^{min} – DP's minimum costs against strategy "i" of nature. $\overline{Z_i}$ -average value of costs. R_i^{max} –maximum risk. In order to estimate risks based on $\|Z_{ij}\|$ the $\|R_{ij}\|$ risk matrix should be created. R_{ij} –risk created by decision corresponding to Z_{ij} costs during each development strategy chooses.

The following criterion uses for choosing an optimal strategy.

Wald's criterion: $\min_i Z_i^{max} = \min_i \max_i Z_{ij} \rightarrow X_j^*$

According to Wald's criterion costs of chosen strategy in any case will not be more than X^*_j.

Apparently Wald's criterion is a cautious criterion (conservative). It is possible to get only assured minimum profit with this criterion.

Laplas criterion: $\min_i \overline{Z_i} = \min_i \frac{1}{j}\sum_{j=1}^{j} Z_{ij} \rightarrow X_s^*$

Apparently Laplas's criterion advices to act according to average value of costs. Lack of Laplas's criterion is that the probability of all strategies (variants) is the same.

Savege's criterion based on choosing of smallest risks among expected.

$$\min R_i^{max} = \min_i \max_j R_{ij} \rightarrow X_j^*$$

Savege's criterion resembles Wald's criterion. Savege's criterion prefers variant with minimum risk.

Gurvich's criterion:

$$\min\left[\alpha \; Z_i^{max} + (1-\alpha)\right] Z_i^{min} \rightarrow X_j^*$$

Here α -" optimist- pessimist" factor, $0 \le \alpha \le 1$. In case $\alpha = 1$ Gurvich's criterion turns into Wald's criterion.

The main point for using Gurvich's criterion is choosing optimal value of α.

Most of analyses show that it's better to admit value of α between 0,5-0,8.

If one of possible energy system development variant matches to all shown criteria then this is the most optimal variant among all.

This variant rarely could be. Generally there are some useful variants in shown criteria for choosing. In this case, in order to choose the best variant among all it needs to use other mathematic methods. It's possible to use expert evaluation methods in this case.

So it is possible and necessary to use facilities of "Game with Nature" theory in choosing the best strategy for energy system development.

CONCLUSION

In nearest future during 7-10 years energy demand of Azerbaijan economy will be 28-30 billion KWh. In order to generate this capacity some strategies should be realized: building of new power plants, reconstruction of existing power plants, regulating of energy system load diagram by economic methods, widely using of renewable energy etc.

It's possible to choose the best strategy (optimal variant of procedures) for energy system by using one or more procedures shown above.

It is possible to realize optimal variant choosing based on "Game with Nature" theory.

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