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MULTICRITERIA OPTIMIZATION OF POWER OBJECTS WORKING MODES WITH FUZZY APPROACH USING

ABSTRACT

The possibility of fuzzy logic means usage for power objects working modes multicriteria optimization problems solution is considered in the report. The variant of structure of the optimization system using procedures of fuzzy output is given. The example of optimization by three criteria for the power station with four power blocks is considered.

Equipment working modes optimization is the one of most important problem of energetic enterprises. There are a great number of works in this field, but it is very difficult to reach a desired result, i.e. to create methodic for obtaining about optimal load distribution between station aggregates (subsystems).

1. ABOUT CRITERIA

The four criteria go to the first place during our optimization. There are: economical, reliability, ecological and manoeuvrability criteria:

$$F = f(F_{\text{econ.}}, F_{\text{rel.}}, F_{\text{ecol.}}, F_{\text{man.}})_{opt.}$$

And, it is obviously, that in different equipment working modes the different criteria go to first place. For example (Fig.1), in the night load minimum (section A-B), when equipment works in non-calculated parameters, in the first turn must be taken into account factors of reliability and economic; during transition from load minimum to its maximum (section B-C) it is essential to take into account criterion of manoeuvrability. And in the case of enterprise situation in the zone of high ecological demands in is necessary to give more attention to the ecological factor.

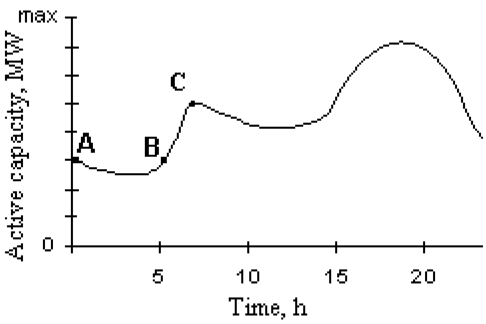

Fig. 1.

Our optimization problem is: by set summary power station load to define loads for working in parallel its aggregates (subsystems), which give minimum general expenditures for production of energy (heat and/or electrical) by maximum level of equipment working reliability, maximum reduction of harmful pollution into environment and sufficient level of equipment manoeuvrability. For solving this problem for today there are three using more often approaches.

1.1. According with first approach, general optimized function is defined as mentioned above criteria weighted sum:

$$F = \sum(k_i \cdot F_i)_{opt.}$$

Weight coefficients k_i are obtained on the basis of expert knowledge. The correct bringing of different nature criteria to united ‘common denominator’, which allows to obtain optimized function, is an **essential problem** of this method. It also can be noticed here, that weight coefficients themselves are needed constant correction, because they are functions of the time.

1.2. Another approach, which is deprived of weight coefficients, assumes detaching of the so-called ‘main’ criterion, by which, immediately, optimization is carried out. Another criteria are taken into account as the limitations. Although this method is easier in realisation, but obtained by it using decision may be satisfactory, but far from optimal.

1.3. According with third approach, all criteria are taken into account not simultaneously, but consecutively. I.e., on the first stage the set of possible equipment working modes are chosen, for example, from the point of view of economical criterion optimization. On the second stage, this set is narrowed due to using optimization by next criterion, and so on for all criteria. As the result, we have at the exit a little set of variants, which are in different measure satisfied all criteria. However, in this case obtained optimization results depend essentially on the criteria considering order, and, as consequence, greatly good variants can be eliminated at the one of the first stages from the further considering. Attempts to do parallel optimization with criteria order changing let to avoid this flaw, but adduce to essential procedure complication.

Going from mentioned above, it becomes obviously, that it is difficult to decide problem of all criteria simultaneous discount and their correct comparison in the framework of the precise mathematical formulation. From the another side, criteria themselves, by essence, are precise only relatively. Criteria calculation mistakes exists always, and in the certain cases we have principally impossibility of such calculation. Using FUZZY approach here, the problem of criterion estimate and variants comparison can be easy solved in the area of fuzzy set theory. Using experts knowledge, variants can be compared by natural and understandable for each operator language on the levels: good variant, middle variant or bad.

2. ABOUT INPUT AND ADDITIONAL INFORMATION

By power station working modes optimization problem solving besides optimization criteria estimation, it is very important to obtain precise, i.e. correspond to the real situation, information and information about technical conditions of equipment.

2.1. Fuel consumption characteristics, which are the base of the economical optimization, changes with time essentially and can deviate from initial value even by 15÷20 % (Fig.2). The set of factors have an effect here, there are several from them: heat exchange surfaces pollution; turbine compaction deterioration, in consequence of frequent start up/shut down operations; presence/absence of repairs and so on. Because of this it is not possible to use only initial fuel consumption characteristics from aggregate technical passport, but it is necessary to take into account operator knowledge about specific aggregate. Also, because many power stations burn more then one sort of fuel, the fuel consumption characteristics estimation in coordinates 'price - power' problem arises. By deciding this problem we have to take into account more expensive fuel share at the night daily load graph minimum. In this conditions greatly successful is occurred operator knowledge using for real fuel consumption characteristic estimation, when operator divides all characteristics to fuzzy areas of 'good', 'middle' or 'bad' characteristics.

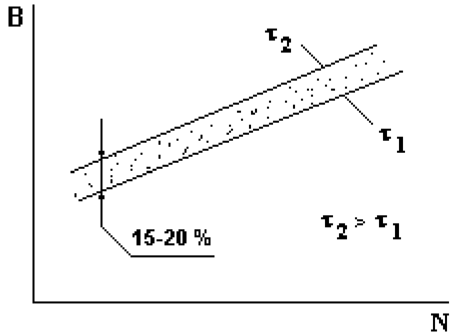

Fig. 2.

2.2. Load graphs, which power station must to provide, are approximate very often in our modern conditions. They lay in certain variation corridor (Fig.3). That's why, choosing between distribution load variants by power station equipment working modes optimization, it is also conveniently to set daily loads in the terms of fuzzy approach as 'high', 'middle' and 'low'.

2.3. Very often by power station equipment working modes optimization, obtained result can not be realized in practice because of equipment technical condition. For example, power block smoke exhauster can not be able to support high block power, recommended by optimization results, because of its technical condition. In such cases by execution of optimization process it is necessary to generate priority modes set and, in the case of impossibility of best result realization, it is necessary to take next variant in the set.

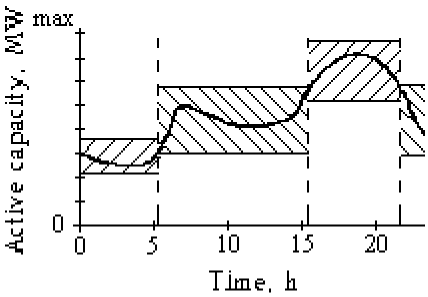

Fig. 3.

3. ABOUT GENERAL APPROACH TO OPTIMIZATION PROCESS

According with noted above, it is possible to offer, as a one of possible variants, the next generalized scheme of load distribution optimization execution (see Fig.4):

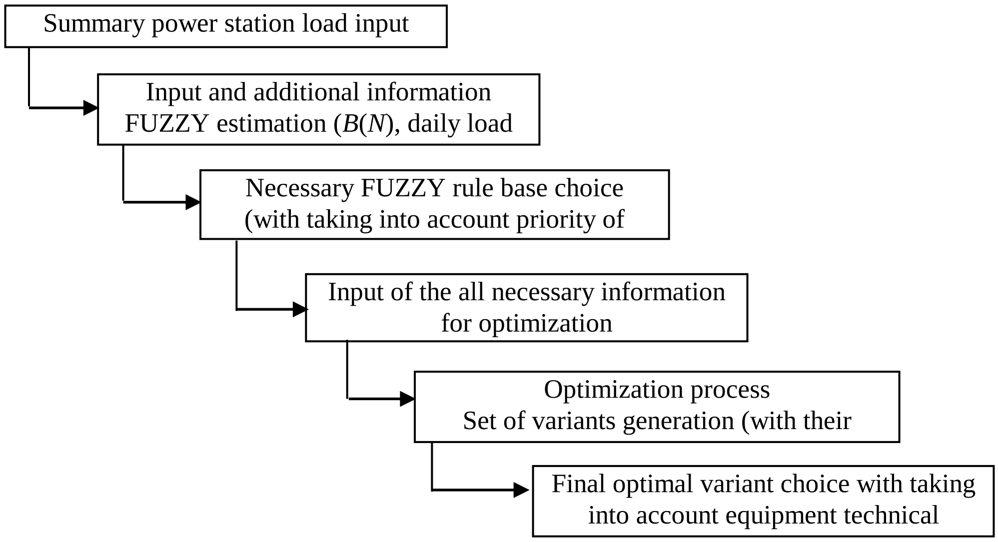

Fig. 4. Generalized scheme of load distribution

It is possible to use the next membership functions for $B(N)$ characteristics quality (Fig.5, where $\Delta B = (B^{curr}(N) - B^{init}(N)) \cdot 100\% \; / \; B^{init}(N))$ and daily load graphs (Fig.6).

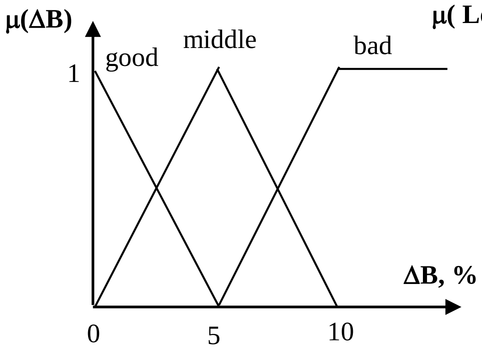

Fig. 5. MF example for the fuel consumption characteristics

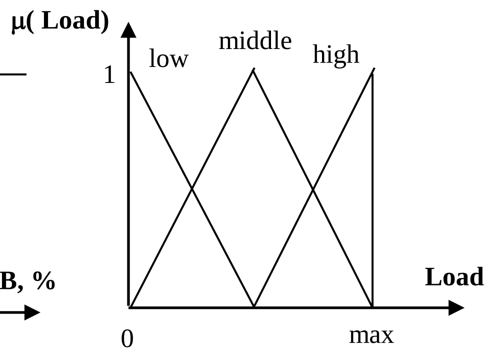

Fig. 6. MF example for the daily load graphs

For the result, i.e. for the value, which is preference degree of concrete variant, it can be used the membership function, shown in Fig.7.

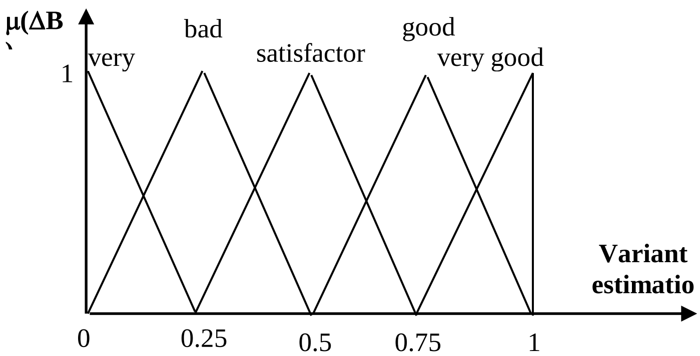

Fig.7. MF example for the optimization result

4. ILLUSTRATING EXAMPLE

Let's suppose, that it is necessary to distribute set summary power station load 1140 MW between its 4 power blocks with the equal capacities of 300 MW. The economy, ecology and reliability characteristics of each block [1] are given below (maneuverability criteria will not be taken into account for simplification of further calculations):

- for fuel consumption (economy criterion) f_{1j} (j = 1,2,3,4), [t/h]:

$$f_{11} = 8 + 29.6P_1 + 2.08P_1^2, \qquad f_{12} = 10.6 + 14.3P_2 + 7.84P_2^2,$$
$$f_{13} = -2.7 + 28P_3 + 1.04P_3^2, \qquad f_{14} = 5.1 + 26P_4 + 1.14P_4^2.$$

- for harmful pollution into environment (ecology criteria) f_{2j} (j = 1,2,3,4), [t/h]:

$$f_{21} = 0.1995 + 0.2858P_1 + 0.0295P_1^2, \qquad f_{22} = 0.133 + 0.1905P_2 + 0.0197P_2^2,$$
$$f_{23} = 0.0255 + 0.0528P_3 + 0.186P_3^2, \qquad f_{24} = 0.017 + 0.0352P_4 + 0.124P_4^2.$$

- for non-reliability f_{3j} (j = 1,2,3,4):

$$f_{31} = \begin{cases} 5.688 - 2.241P_1, \ P_1 \le 2.5; \\ 0.084 - 0.042(P_1 - 2.5), \ 2.5 < P_1 \le 2.9; \\ 0.067 + 2.332(P_1 - 2.9), \ P_1 > 2.9; \end{cases}$$

$$f_{32} = \begin{cases} 4.551 - 1.783P_2, \ P_2 \le 2.5; \\ 0.094 + 0.22(P_2 - 2.5), \ 2.5 < P_2 \le 2.9; \\ 0.182 + 1.073(P_2 - 2.9), \ P_2 > 2.9; \end{cases}$$

$$f_{33} = \begin{cases} 3.206 - 1.261P_3 + 0.08P_3^2, \ P_3 \le 2.5; \\ 0.5535 - 2.274(P_3 - 2.5) + 2.954(P_3 - 2.5)^2, \ P_3 > 2.5; \end{cases}$$

$$f_{34} = \begin{cases} 2.132 - 0.847P_4, \ P_4 \le 2.4; \\ 0.0992 - 0.0865(P_4 - 2.4), \ 2.4 < P_1 \le 2.9; \\ 0.05595 + 1.472(P_4 - 2.9), \ P_4 > 2.9; \end{cases}$$

where P_j is load of the j-th block, [100 MW], $2.2 < P_1 \le 3$.

There are countless variants of load distribution, but for the simplification and visualness of the further ordering procedure we'll limited by 15 representative variants, presented in Tab.1.

Table 1.

Var. №	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Block 1,	300	300	300	240	300	300	300	270	270	270	285	300	280	280	280
Block 2,	300	300	240	300	300	270	270	300	270	300	285	280	300	280	280
Block 3,	300	240	300	300	270	300	270	300	300	270	285	280	280	300	280
Block 4,	240	300	300	300	270	270	300	270	300	300	285	280	280	280	300

Using approximate economy, ecology and reliability characteristics of each block, given above, values of these criteria have been obtained.

With the help of program product 'MatLab' (version 5.3.1.29215a R(11.1)) and its applications 'Simulink' and 'Fuzzy Toolbox' for each variant of Tab.1. has been obtained value of this variant priority.

As a part of optimization process, which provides Fuzzy-ordering, it was be used the structure shown on Fig. 8. For fuzzification of each criteria was used the same membership functions, but with, of course, different limits. For output value of the variant 'Priority' was used membership function like in Fig.7, but only with 3 terms (bad, middle and good).

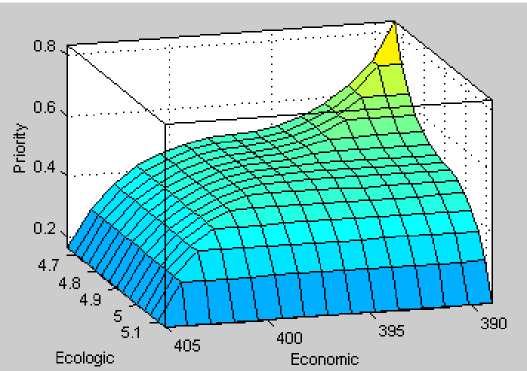

Fig. 9.

Rule base for interference procedure consisted from 27 rules (all possible combinations of input values), all criteria had equal importance. Output surface for priorities are given on Fig.9 (for middle Reliability criteria equal 0,945). Other surfaces are similar.

Results, obtained after computer processing off the all 15 variants, are presented in Tab.2.

Table 2.

Var. №	1	3	4	5	6	7	8	9	10	11	12	13	14	15
Priority	0.163	0.472	0.204	0.401	.362	0.577	0.330	0.496	0.406	0.455	0.487	0.519	0.52	0.39
Place	14	6	13	9	11	1	12	4	8	7	5	3	2	10

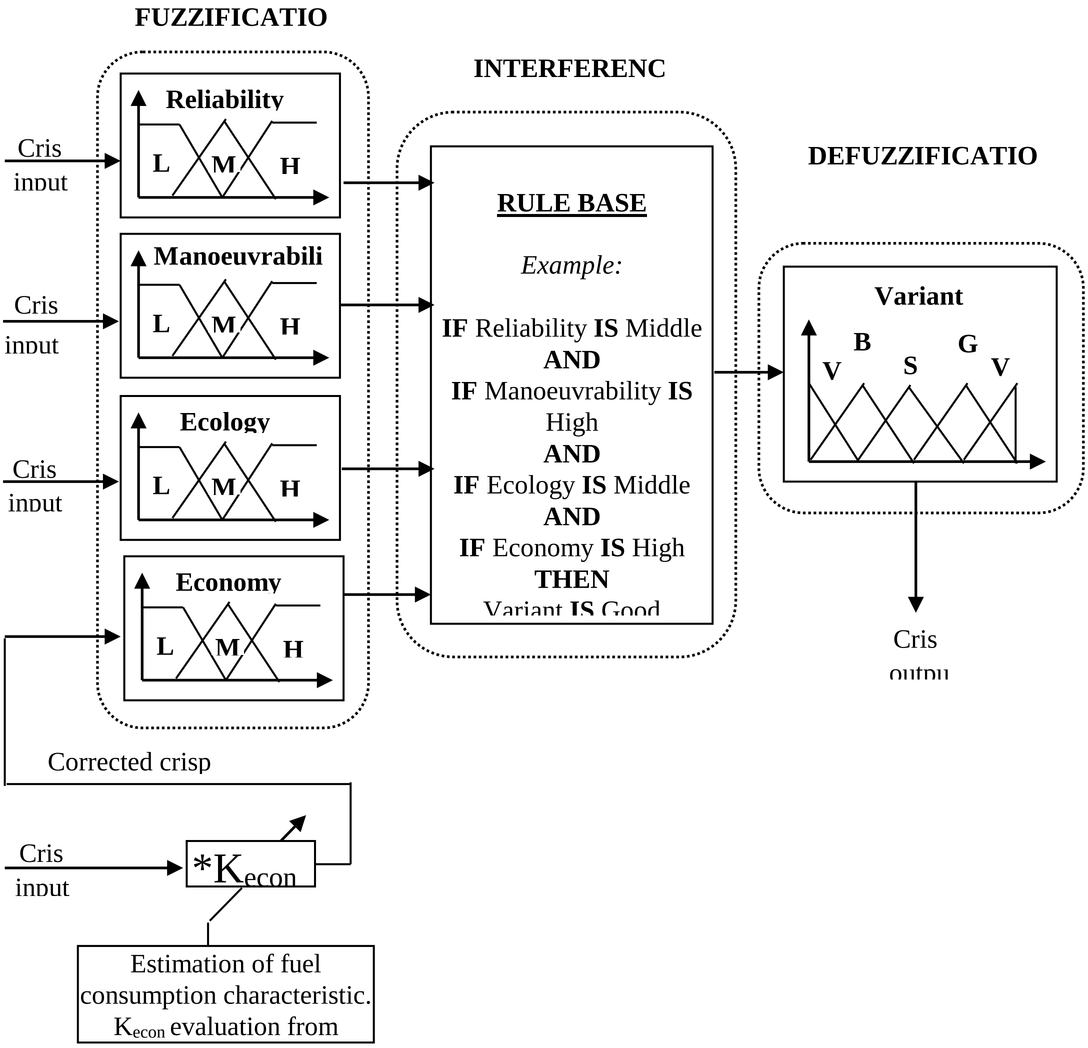

Fig. 8. Possible structure for variants FUZZY-

According with represented results the best of considered variants are the next load distributions between blocks 1-4 correspondingly: 300, 270, 270, 300 MW; 280, 280, 300, 280 MW; 280, 300, 280, 280 MW (variants 7, 14 and 13), moreover last two variants are very close to each other. If, by any reason, these three variants are can not be realized in practice, it is possible to take into account the next by priority variants (№ 9, 12, 3 and so on).

5. CONCLUSION

5.1. Proposed in the report Fuzzy-approach to the summary plant load distribution between its separate power blocks optimization problem allows to compare correctly criteria, which are different by their nature, by using language, understandable for each operator.

5.2. Offered possible structure for variants FUZZY-ordering assumes taking into account of the input information deviation from initial values.

5.3. Proposed approach is in the phase of developing and there are a lot of problems here, for example: creation of corresponding rule bases, estimation of the calculation time, choice of the suitable optimization algorithm, realization of necessary rule base choice etc.

The work was supported by INTAS grant № YSF 2002-211

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