Effective electrical equipment operation process management based on automated information decision making support

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Abstract. The article studies the issues of ensuring electrical equipment operability during operation process, as an indicator of reliable and efficient power supply of heterogeneous consumers. The problem of electrical equipment operation process managing is considered from the point of view of many technical and economic factors that affecting decision making and the priority of taking measures to emergency prevention. The concept of information decision-making support, aimed at controlling the electrical equipment actual condition and planning work to ensure its operability in the short and long term, was proposed. An example of the information decision-making support implementation when choosing objects with the maximum risk of operability loss was given.

1. Introduction

In order to ensure uninterrupted electric power supply to industrial and civil facilities there is a need of reliable and efficient operation of all elements of a complex, distributed system for the production, transmission and use of electric energy [1, 2]. Due to the large amount of electrical equipment (EE) involved in these processes, there is a problem of finding an effective technology for managing their operability for reducing the number of emergencies and minimizing technological and economic damage. Such a technology requires of information on the EE actual condition and the possibility of its assessment for the short or long term [3-5].

Current trends in the electric power industry reforming suppose widespread using of information technologies that help to create highly adaptable, stable and reliable electric grids [6, 7]. The implementation of information-measuring, information-analytical and information-control systems, as an integral part of such grids, gives an opportunity for EE condition monitoring and diagnostic and for managing of its operation process, providing personnel with effective decision making support [8-11].

2. The problem of electrical equipment operation process managing

The goal of EE operability managing suggests a reliable assessment of its condition and the choice of a further operation scenario (maintenance, repair, diagnostics, etc.). The scenario selection procedure is multicriteria, based on the ability to process and analyze heterogeneous information about the object (both quantitative and qualitative) and can be represented by a set of the following parameters [12]:

\[ \langle F, A, K, Y, W, D, P, S \rangle, \]

where \( F \) is the goal of managing; \( A=(A_1, \ldots, A_n) \) is a set alternatives for the managing actions implementation (equipment, groups of EE, separate facilities); \( K=(K_1, K_2, \ldots, K_M) \) is the a of decision-
making criteria of technical, technological, economic and other content; \( Y=(y_1, ..., y_L) \) is a set of estimates of alternatives by criteria; \( W=(w_1, w_2, ..., w_M) \) is an expert preference system (weights of criteria); \( D \) is the rule for choosing alternatives; \( P=(p_1, ..., p_n) \) is a final priorities of the alternatives; \( S=(s_1, s_2, ..., s_V) \) is a set of operation scenarios.

The goal of management, as a rule, is to minimize the total EE operating cost through the timely taking of measures to maintain and restore its operability. Priority \( P \) suggests that we identify an EE that has the highest criticality degree in terms of the need for control actions, taking into account both technical and economic operation aspects. The actual EE technical condition (TC) is one of the determining factors, and it should be continuously or periodically assessing by various software and hardware and different data processing methods [3, 5, 8]. We should note that in the conditions of limited resources (finances, personnel, etc.) it is not always possible to carry out the maintenance of the entire EE during the current planning period.

Thus, the goal of effective EE operation managing is to quickly react to changes in the EE condition and to carry out the required measures in the first place for the highest priority objects [11]:

\[
\sum_{i=1}^{N_v} p_i r_i \rightarrow \max,
\]

\[
\sum_{i=1}^{N_v} r_i C_{ij} \leq L_{i,j}^{\text{max}}
\]

where \( r_i \) is a variable that determines the feasibility of including the \( i \)th equipment in the control actions schedule \((r=1)\) or exclusion from consideration in the case of a low priority value \((r=0)\); \( p_i \) is the final priority of the \( i \)th equipment based on the analysis of key criteria characterizing the equipment condition and other technical and economic indicators; \( N_v \) is the total number of EE involved in the planning task (based on the results of the condition control); \( v \) is an indicator of using the specific operation scenario; \( C_{ij}, j=1,J \) is the value of the \( j \)th resource consumption when carrying out maintenance of the \( i \)th equipment; \( L_{i,j}^{\text{max}} \) is the amount of the \( j \)th resource for the relevant maintenance work area in the planning period.

The solution of the optimisation problem gives the opportunity of defining priority for groups of EE for each possible EE operation scenario, requiring any costs (repair, maintenance, diagnostics, etc.). The system of constraints (3) is formed taking into account the categories of resources used (finances, labour input, materials) and those boundary values that are determined by the EE serving organization for the considered planning period.

3. Automates decision making support for electric equipment operation process

In order to solve the problem (1), it is advisable to use modern information technologies that will provide information and analytical support [13] for the personnel involved in decision-making for the EE operation process managing.

Figure 1 shows the key stages of automated information decision-making support (AIDMS), aimed at maintaining the EE operability due to timely control actions (carrying out the required measures).

It is supposed that EE condition is in real-time or periodically controlled using specialized software and hardware (see Fig. 1, block 1). A comprehensive assessment of EE actual condition [5, 8] is made (see Fig. 1, block 2) taking into account the received information about the values of the key technical parameters by defining the EE condition criticality class and the appropriate recommendations for ensuring its operability. Information on the EE parameters and its operation process is recorded in the appropriate database.

In accordance with the results of the TC assessment (see Fig. 1, block 3) the lists of EE with various recommended operation process scenarios including the defects search, localization and elimination are generated [8, 11].
Calculation of EE priorities for measures to ensure operability

1 Electrical equipment monitoring and technical condition assessment

2 Choosing the EE operating scenario and developing recommendations

3 Formatting of EE alternatives list for each of the operation scenarios

4 Calculation of EE priorities for measures to ensure operability

5 Planning measures to ensure the EE operability

6 Making final decisions on the EE operation process managing

7 Writing / reading data from the EE operation database

Begin

Current data on the EE operation

Measuring of EE parameters values during operation and their analysis (data processing subsystem)

Issuing a conclusion on the degree of the EE condition criticality and measures to improve it (subsystem of the TC integral assessment)

Grouping EE in accordance with the results of the TC assessment and recommendations for its further operation

Assessing of technical and economic indicators (criteria) based on information about the EE operation and its actual condition (ranking subsystem)

Solving the multicriteria optimization problem with limited resources (planning subsystem)

Formatting of the short term/long term work schedules

Current operability data

Technical and economic indicators

Financial and economic data

Priorities data

Work schedules

Figure 1. The flowchart of the AIDMS for managing the EE operation process.

For each EE an integral priority indicator is calculated (see Fig. 1, block 4), taking into account its actual TC and different further operation scenario. You can use multicriteria analysis techniques considered in [12, 14] to find the EE priority.

In this case, the values of the selected decision-making criteria are determined taking into account the available statistical data and the experience of experts on the EE operation process. Also the amounts of resources required to carry out work of the EE operability maintaining are estimated.

EE priorities found are used in the multi-parameter optimization problem (1)-(2), which can be solved both in the classical way and using evolutionary optimization methods. As a result, a planned list of EE which highly requires the maintenance to ensure its operability is formed (see Fig. 1, block 5). The obtained maintenance schedules are used to make final management decisions and adjust the EE operation process strategy.

Thus, the automated information decision making support gives possibility to: monitor the dynamics of EE key parameters changes, as well as its actual or forecast condition; evaluate the EE priority from the point of view of different measures to ensure operability, taking into account the
selected decision-making criteria; keep statistics of maintenance and repair and plan activities for the short / long term, taking into account the selected planning horizon and available resource constraints.

4. An example of using automated information decision-making support technique

Consider the features of the proposed AIDMS decision-making technique on the example of the operation process of EE used to electric power supply of oil-producing facilities in the Perm Krai. We considered actually functioning equipment (transformers and high-voltage circuit breakers with different life time) as different alternatives. Information for EE condition assessing, subsequent analysis and selection of its operation process scenarios was obtained from reporting and regulatory and technical documentation, as well as from the interviews with experts [15, 16].

We used the structure of decision-making criteria proposed in [14.] to assess the EE priorities. Figure 2 shows the distribution of EE condition estimates by key technical and economic indicators, reduced to a single scale from 0 to 1.

![Figure 2. Distribution of EE priority according to different decision-making criteria: diagnostic assessment of TC ($K_1$); actual resource ($K_2$); probability of failure ($K_3$); failure criticality ($K_4$); costs to ensure operability ($K_5$); performance ($K_6$).](image)

To find the integral priority value, various methods and decision functions can be used. At the figures 3 and 4 you can see an example of the dependence between the EE technical condition complex indicator ($K'$) and the indicator of EE technological significance ($K''$), as well as the final EE priority estimates using linear, multiplicative and weighted average convolution according to the [14].

![Figure 3. The dependence of the EE priority estimates from the values of the factors $K^1$ and $K^2$: linear convolution (a); multiplicative convolution (b); weighted average convolution (c).](image)
Figure 4. Alternatives priority allocation for different aggregation methods.

The obtained priority estimates are used to making schedules for maintaining the EE operability (for the case in the article: advanced diagnostics or repair), which allows focusing on the equipment with the maximum risk of failure, and thereby minimize the related financial costs.

5. Conclusion
The proposed approach for AIDMS in managing the EE operation process is aimed at helping engineering and technical personnel in developing an effective strategy of power energy facilities operation for the short and long term.

Orientation to the EE monitoring and diagnosing technologies, as well as the EE priorities system construction, makes it possible to reasonably determine the order and amount of work to maintain its operability (in accordance with the actual TC) in order to ensure maximum reliability and fault tolerance of power supply systems.

The proposed solutions can be considered as particular implementation mechanisms of a united intellectual information and diagnostic system for monitoring and controlling the EE condition during its operation process [17].

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