In the process of operation electrotechnical equipment of electric power systems (EE) undergoes the action of the wide spectrum of the factors, which cause worsening in its technical state (TS) and reduction in the operational reliability.

Technical diagnostics is one of the ways of increasing in reliability and efficiency of work. The purpose of diagnostics consists of the estimation and the action on TS of equipment according to the information about the developing faultiness and the defects, of conducting the maintenance and repair in time (MR), of accumulation and transmission of the required information to manufacturing plants and to developers for improving the produced equipment and improvement in the quality of the projects of stations and substations.

Data of the analysis of operation, reasons and consequences of the refusals of equipment at the power stations of Russia [1, 2, 3] show that the high degree of its deterioration is the basic reason for reduction in operational reliability nowadays. During the guarantee of operational reliability of equipment important place occupies the system of MR. On the thermal and atomic power plants in the prime cost of the production of electric power the component of expenditures for repair composes 10% - 15%. During the period of planned operation the expenditures for MR of separate specific equipment in 3 - 4 times exceed its cost. Operation of EE requires the creation of the more advanced systems of control, diagnosis and development of more progressive forms of MR equipment depending on TS.

Systematic and information bases and special features of diagnosis of EE are sufficiently in detail presented in the specialized literature. Therefore is given below only the common survey of methods and technical equipment of control, developed in Russia for the electrotechnical equipment.

The analysis of causes for appearance and display of defects of EE shows that TS of each of them is characterized only by in its own individual and general signs. After combining all signs and means of diagnosis into the separate groups we will obtain the structure of diagnosis of EE, that consists of three levels and subsystems: performance checkout, the exposure of defects, estimation and the prognosticication of capacity of work. In this case each subsequent level uses results of previous ones.

The systems of control and diagnosis at present are represented by local and integral methods and means. To the integral means can be attributed, for example, the control of the temperature of current-carrying parts and contacts, the control of insulation resistance, the control of dielectric strength, the means, which react to the processes accompanied by arcing and by discharges, vibration processes and others. To the local means relate, for example, the means, which reveal the frustrated launching of electric motor, loop fuse in the winding of stator and others.

The concept of the creation of the systems of diagnosis is developed step by step, beginning from the use of the regular instruments, supplemented with the missing sensors and devices, overgrowing consecutively into the automated systems of control and diagnosis, into the automated control systems of the technological process of the electrical part of the stations, then power station as a whole and then into the regional and branch system.

To the most promising methods and the means of control and diagnosis can be attributed the following: infrared thermographs, the chromatographic analysis of the oil-filled equipment, the control of the dielectric characteristics of isolation, vibrodiagnostics, the control of electrophysical parameters of EE, etc.

Let us examine in more detail the application of the methods of diagnostics and system MR "due to the state" for EE systems of its own needs of Thermoelectric Power Station, developed with the participation of the authors. To the described developments more than 20 author's certificates of invention are obtained.

Moistening their isolation is one of the widespread defects, which lead to the refusal of electric motors. For determining the value of insulation resistance under the load there is a method, based on the artificial imposition on the power circuits of control voltage from the outside source and the fixations of the value of leakage current through his isolation. With the reaching by control system the sensitivity, equal to the minimally permissible insulation resistance Rmin, it acquires qualitatively new property - to reveal the nascent damage of isolation in the process of operation, which has high preventive value.

On the powerful electric motors with the large number of protracted starting about 40% of damages appears as a result of the break of the rods of rotor. Several versions of devices for the early development of the breaks of rods are
created. They are based on the exposure of the component of the alternating frequency, directed in the circuitry of the stator of slowly damped free aperiodic component of the current of rotor or based on the control of impulses from each rod of rotor or value of slip.

It is developed the protection, which reveals loop and interphase short circuits with the aid of the built-in the winding stator of the electric motor the additional annular magnetic circuit, which reacts to the flow of the null sequence of separate sections. The installation of this magnetic circuit is achieved in the process of manufacture or repair and adapts in the complex with the heat shield.

The fact of the sparking of brushes is used for the control of the state of brush-contact apparatus, since the process of commutations always accompany radio interference in the range 1000 - 3000 Hz. The method adapts together with control system of the uniformity of current distribution in the branches in the process of work. Additional measuring brush is settled for its realization.

Continuous recording of the parameters determining resource is conducted for the control of the wear of resource in the process of operation. With reaching of the given values of the wear of resource MR or extended volume of diagnosis is assigned. Control of the wear of resource is conducted for the switches, the transformers and the large electric motors.

At the basis of control of the wear of resource of switches the dependence of the wear of contacts on the value of short-circuit current lies.

Control of the wear of the resource of transformers is carried out on the base of the model of the thermal wear of the isolation of windings. The algorithms of the calculation of the relative wear of isolation depending on the value of load and hottest-spot temperature of transformer taking into account ambient temperature are developed. Control can be realized within the framework of automated control system (ACS) of engineering procedure of the electrical part of the stations or in the form of the local automated systems.

Control of the wear of the resource of the isolation of electric motors is conducted because of the fixation of the number and duration of starting and the registration of real loads.

Development and operation of the enumerated means allowed to obtain the data about the regimes, to estimate statistical and integral operating characteristics, to formulate requirements to the manufacturing plants of equipment.

The operation of the system of the continuous individual control of the insulation resistance of connections 6 kV, in particular, showed that at the frequency of 1 Hz the resistance of electric motor during the work composes value on the order of 2.5 MΩ. In the process of the control of insulation resistance the sudden moistening of the isolation of stator were revealed and the refusals of the group of electric motors were prevented.

It is developed the automated system of control of the state of electrotechnical auxiliaries (ASC EA). ASC EA works in the real time and is intended for the control of the regimes of the work of electrotechnical equipment and for the determination from the developed algorithms the values of the worn resource: electric motors, transformers and the switches with a voltage of 6 kV.

Output information of ASC EA is presented to operational personnel. On the basis of its analysis the recommendations on the rational operation of the auxiliary mechanisms of power stations and the designation it is timetable and volumes of MR are manufactured.

ASC EA represents the interconnected complex of technical and software with the necessary collection of sensors and devices, connected with computers. There are programs, which ensure vitality of ASC EA with the real-time operation.

A composition and a quantity of sensors is determined by tasks of ASC EA and quantity of controlled equipment. From computers along the sequential channel the processed information enters another computer, where the problems of ASCP of power station are solved.

The wear of the isolation of winding is evaluated for the transformers. Its load periodically is tracked for this and the hottest-spot temperature of winding is calculated.

For the control of the wear of the resource of switches in ASC EA a form and a quantity of the produced commutations from each current is tracked.

Output information of ASC EA is concentrated in the tables on the display screen or can be printed on the printer. In the tables it is placed also the information about the value of the worn resource and the former regimes.

It is developed the procedure of the formation of schedule chart MR "due to the state" EE of own needs of power stations. According to this procedure for describing the procedure of control of the states of the process of operating different technological groups of EE is used the matrix of control \[ Y = \left[ K_{ks} \right]. \] Matrix rows correspond to the numbers of equipment in j-group. Each of the groups contains i - units of the equipment of one technological designation. Columns s correspond the states of the process of operation (repair, reserve, work, etc.). The columns of matrix Y are named the vectors of control of the states of the process of operation. The logical values are matrix elements: 1 - if equipment is in state s or by 0 - if equipment is not in this state. The matrix of optimum or close one to the optimal strategy of MR Yoct is located with condition \( Y_{opt} \rightarrow P_{min} \), where \( P \)-penalty function, which considers deviation from the matrix of the optimal strategy, caused by
limitations to the number of repair personnel, by the deviations of the operational probability of failure-free operation from that permitted or given one and index of priority of the priority of fulfillment MR, by technological limitations to the number of units of equipment j-groups, which simultaneously can be in the work or in the reserve and by other conditions. The quantitative assessment of the priority of fulfillment of MR is found by formula Qi = (1 - Pj) Ri, where Ri - complex parameter of technical state, for example, the value of the wear of resource, actual nonfailure operating time and so on, i - unit of equipment, and Qi - probability of failure-free operation.

For the record of the simulator of the procedure of the composition of the schedule chart of works on maintenance were accepted the following designations of the parameters and concepts:

N - total quantity of EE on the power facility; m - quantity of groups of EE, obtained by the partition of set N according to the sign of technological designation; j=1..., m - ordinal number of group; Kj - quantity of EE in each j-group, i = 1,..., k - ordinal number of EE in j - group; Pij - probability of failure-free operation, calculated taking into account the results of the control of the modes of operation and factors for i- EE by j –group, influencing in this case; [ Pj ] - the normative value of the permissible probability of the failure-free operation EE of j -group; [ K ] - the permissible quantity of EE of one technological designations, which simultaneously can be in the repair and the reserve without the disturbance of technological process; LP - quantity of personnel, necessary for conducting the repairs of EE; [ LP ] - the disposed number of personnel on the power facility; LRv - list of EE, requiring conducting repair (v=1,..., 7). Moreover list LRv does indicate the following, if v (the values) is taken:

1 – the list of the equipment, which requires conducting repair in j-group;
2 – the list of the equipment, which requires conducting repair as a whole on the power facility;
3 – the priority list of the equipment, which requires conducting repairs in j-group;
4 – the priority list of the equipment, which requires conducting repairs in j-group taking into account the limitations;
5 – the total priority list of the equipment, which requires repair on the power facility;
6 – the total priority list of the equipment, which requires conducting repairs as a whole on the power facility taking into account the limitations;
7 – the priority list of the equipment, which requires conducting repairs for the following planned period.

The formation of the schedule chart of repairs of EE is possible via the realization of the mathematical model, represented in the table.

Table. Simulator of the formation of the schedule chart of the repairs.

<table>
<thead>
<tr>
<th>Position of the model</th>
<th>Simulator of the formation of the schedule chart of the repairs</th>
<th>Result of fulfillment conditions of the model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pj ≤ [Pj], j = 1, ..., m;</td>
<td>LR1 and LR2</td>
</tr>
<tr>
<td>2</td>
<td>Qj ≥ Qi+1, i = 1, ..., k;</td>
<td>LR3 and LR5</td>
</tr>
<tr>
<td>3</td>
<td>Kj ≤ [Kj], j = 1, ..., m;</td>
<td>LR4 and LR5</td>
</tr>
<tr>
<td>4</td>
<td>Lp ≤ [Lp]</td>
<td>LR6</td>
</tr>
<tr>
<td>5</td>
<td>( Y_{opt} \to \min P_f ), j = 1, ..., m;</td>
<td>( Y_{opt} )</td>
</tr>
</tbody>
</table>

The order of the calculation of parameters Qi and Py, entering the mathematical model, an example of the use of a penalty function, and the illustration of the selection of the matrix of the optimal strategy of control of the operative conditions of group EE are examined into [2].

Procedure is oriented to the realization with the aid of computer in the composition of the series of problems ASCP of power station. In the information plan the procedure is based on the developed complex of technical equipment and ASC EA, realized by means of SCADA - systems.

Thus, the data analysis of operation, reasons and consequences of refusals of EE at the power stations of Russia shows that diagnostics is one of the effective means of increasing in reliability and efficiency of the work of the systems of power engineering. The developed to the present time local and automated systems of protection, control and diagnosis of EE of power stations make it possible today to increase safety and efficiency of work, to decrease the number of sudden turning offs and to realize maintenance and repair of equipment "due to the state".

REFERENCES

