Planning Maintenance of Power Generating Equipment in Market Environment with Regard for Reliability

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Abstract—An approach to the annual scheduling of maintenance of the generating equipment of power systems was proposed. Descriptive formulation of the problem and mathematical model of its solution were given with regard for the operational conditions of the deregulated power systems and maintenance of the power equipment in the market environment. The maintenance schedule was optimized by the criterion for maximum profit of the generating company. Penalty on the generating company for violation of the treaty commitments to deliver electrical energy and power to the market network because of the maintenance of the generating equipment was included in the objective function, which enables one to coordinate the interests of the generating company and other market subjects.

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1. INTRODUCTION

Maintenance scheduling for the generating equipment of the electrical power systems (EPS) is one of the reliability problems solved in the course of EPS operation. It is topical for both the vertical integrated and deregulated EPS’s. In the former EPS’s, all structures including those responsible for maintenance are under a common centralized control. The common task of providing reliability of EPS and supply of consumers by power of the desired quality under the minimal industrial costs is executed with their joint participation. Division of property and the market mechanisms introduced in control gives rise to independent market subjects having different interests. The generating companies (GC) are interested in getting the maximum profit from the equipment of the power stations, the power consumers, in the minimal price for electrical energy. The system operator (SO) has to do its best to supply reliably the consumers with regard for the possibilities and interests of all market subjects. Consequently, in the market environment the problem of scheduling maintenance of the generating EPS equipment may be solved using different, both economic and reliability, criteria [1–6]. Independently of the selected criterion, a mechanism should be provided to coordinate the interests of all market subjects at selecting the times of scheduled repair.

The present paper considers the problem of annual scheduling of maintenance of the generating equipment of power stations belonging to or under control of a generating company operating in the market environment. The maintenance schedule is optimized by the criterion for maximum profit of the generating company with regard for reliable supply of the consumers. The repair schedule is ranked in importance of the demanded repairs on the basis of combination of two strategies: preventive maintenance (PrM) and repairs caused by the state of equipment. The PrM’s are carried out at the averaged normative times disregarding the equipment state, and in the case of equipment failure unscheduled renewal repairs are carried out [7]. The PrM strategy enables one to get ready

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for repairs and do them in normative times, improve equipment performance, and provide the desired level of EPS reliability and consumer supply. It enables efficient operation of the equipment in the conditions of the rigid centralized scheduling and optimal loading of the equipment, but it is not advisable economically. The technical state-based strategy lies in that the scheduled repairs are carried out taking into consideration the actual equipment state as determined by the diagnostic methods and facilities [8]. This repair strategy enables a fuller use of the equipment resource and is most efficient at operating complicated equipment with high repair costs. The present authors suggest to optimize the repair schedule on the basis of a combination of both strategies—PrM and state repairs—allowing one to take into consideration the interests of the energy producers and consumers.

2. FORMULATION OF THE PROBLEM

According to the PrM strategy, the electric power plants in advance present to the GC the requests for equipment repair in the coming year. These requests are used to compile a general ranked repair list with allowance for the equipment state and reduction in the available plant power at during the repairs. For that, determined is the rating of each repair.

Let us assume that the level of technical state of the equipment is estimated by a conventional index $TC = 0, 1$ whose value is established from the results of technical diagnosis [8]. The lower $TC$, the more dangerous further operation of the equipment which must be repaired at earliest convenience. The repair rating ($RE_i$) is calculated from

$$RE_i = P_{ci} (1 - TC_i), \quad i = 1, I,$$

where $I$ is the number of planned repairs in the planned year, $P_{ci}$ is the reduction in the available power at $i$th repair, and $TC_i$ is the index of the technical state of the $i$th installation on the repair list.

The planned repairs are listed in the descending order of $RE_i$. At coincidence of ratings, the longer repairs are given preference. This ranking attaches higher priority to longer repairs of the economic high-power equipment with low technical state. Planned repair of such equipment in the optimal time creates favorable conditions for operation of the generating company. Repairs of the low-power equipment take little time and may be carried out during the load dip without detriment to reliability. They do not require great technical and financial resources. If the list includes repairs that were carried over from the preceding year or are privileged fixed-date ones, then independently of their ratings they are put at the list head. For the so-generated list, the problem of optimization of the planned repair schedule is solved as follows.

Given is the repair list of the generating equipment of the power plants operating within the GC framework. It is ranked with allowance for the equipment technical state, degree of equipment impact on reliability, and repair durations. The installation type, its available power, reduction in the plant power at putting the installation into repair, repair duration and its conditions are known for each element on the list. Needed is to determine the optimal times of the planned repairs of the equipment on the list that bring the maximum annual profit to the generating company with regard for the seasonal constraints, incompatibility of individual repairs, potentialities of the repair companies, and the requirements on reliability of consumer supply.

3. MATHEMATICAL MODEL

Solution of the above problem comes to maximizing the GC profit function. The GC annual profit ($PRF$) is defined by the difference between the total annual GC income from supplying energy and power to the market network ($AI$) and the total production costs ($APC$) with allowance for