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Generation planning in Iranian power plants with fuzzy hierarchical production planning

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ABSTRACT

The Power Plants Generation Planning (PPGP) usually encountered complicated problems. In this paper, a new hierarchical approach is applied for generation planning in power plants. In hierarchical approach, the main integrated problem is separated into some sub problems which could be easily solved by multi level models. Higher level models include organization total strategy and lower level models is concerned with detailed accurate planning. When models are broken down into several levels, the solutions of higher level could be considered as inputs for the lower levels. In the proposed structure, amount of future demand is predicted to specify time periods in first level. In the second level, amount of demand for each aggregate period is allocated to different aggregate methods of electricity generation like; steam, gas, combined cycle and hydro power plants in Iran by using Analytical Hierarchy Process (AHP) and Fuzzy Aggregate Production Planning (FAPP). This allocation is carried out according to two criteria of "share of total electricity generated by each type of generation" and "amount of environmental pollution". AHP and Fuzzy Disaggregate Production Planning (FDAPP) are applied to determine best utilizing power plants for generation in the final level. The proposed Fuzzy Hierarchical Production Planning (FHPP) outputs express optimal combination of power plants which contribute for demand satisfaction.

1. Introduction

Electricity production planning which is called generation planning in Power Systems (PS) is divided into: long-terms, mid-term and short-term planning [1]. Planning and operating modern electric PS involves several interlinked and complex tasks. Optimal production plan, however, is difficult optimization problem for thermal and hydro power plants, which obviously could be solved with proper computer tools.

Long-term energy generation planning is an issue of key importance to the operation of electricity generation companies. It is employed for strategic planning, budgeting, fuel acquisitions and so on to provide a framework for short-term energy generation planning. A long-term planning period (assumed one year) is usually subdivided into shorter intervals of weeks or months, for which parameters like load–duration curve should be predicted, and variables as the expected energy generations of each plant unit must be optimized.

The problem of planning the production for the next 10–30 days is known as the mid-term planning problem in PS management. Production planning problems with up to one week time horizon is known as short-term planning.

The short and mid-term planning problems could be considered alike principally, except in some specific conditions, the reason not treating them equally is that problems may be more or less relevant on variety of time horizons. Since uncertainty exists in prediction of electricity demand and also electricity price, the mid-term problem can be made rough. On the other hand, the short-term model can be detailed due to the relatively good predictions that can be derived for the next few days. This high level of detail implies that a short-term model, in practice, can only implement one district heating system at a time.

Another purpose of the mid-term model is to model the restrictions that connect the different systems. The principal planning procedure is solving the mid-term problem; outputs of the mid-term problem are used as the inputs to the short-term problem.

Mathematical optimization algorithmic methods have been used over the years for many PS planning, operation, and control problems. There are many uncertainties in PS problems because PS are large, complex, and geographically widely distributed. An optimization problem is a mathematical model where main objective is to minimize undesirable things (e.g. cost, energy loss, errors, etc.) or maximize desirable things (e.g. profit, quality, efficiency, etc.), subject to some constraints. The main advantages of algorithmic methods include:

1. Optimality is mathematically rigorous in some algorithms.
2. Problems can be formulated to take advantage of the existing sparsity techniques applicable to large-scale PS.

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3. There are a wide range of mature mathematical programming technologies, such as Linear Programming (LP) and Quadratic Programming (QP), Nonlinear Programming (NLP), integer and mixed integer programming, Dynamic Programming (DP), et al. [2].

In spite of this advantage, in most of the mathematical optimization production planning, the decisions are made at the separately models with different time horizon and without a feedback and hierarchical structure. It is important that the decisions made at an upper level of planning (long-term) be imposed to the lower level (short-term) as constraints. Also in real problems, exact and sufficient detailed data don't exist for short-term planning. But it is possible providing exact data for long-term planning. So upper level of planning is solved and its outputs are used as a validation criterion for lower level outputs.

Production planning in the electricity industry and PPGP problems are very complex with extensive features. Also, due to the specific condition of respective product, electricity generation planning is mainly different from other production planning problems with specific characteristics. Some of these characteristics are:

1. Not to be able to suppose the backorder state.
2. Generating electricity in a specific period to use it in other periods in future is not directly possible.
3. Considering specific characteristics and exclusive state of this product, it requires flexible and specific generation planning which means it must generated more than predicted to satisfy demand.

An appropriate approach to alleviate this deficiency is to use FHHP by introducing imprecise/fuzzy data along with the soft constraints, allowing some minor deviations from the outputs of the upper level while making a decision in the lower level.

A rigorous mathematical analysis of Hierarchical Production Planning (HPP) is found in the pioneering work of [3]. Theoretical work on the topic has followed [4–6]. Nowadays HPP method is used as a structured method in various fields. In general the essential advantages of using HPP approach are as follow [3]:

1. Planning process complexity decreases due to main problem decomposition into a series of continuous sub problems. Solving these sub problems is very simple and economical. In hierarchical approach, integrated problem is decomposed into sub problems that need very low calculation and computer memory. Therefore, production planning problem solving is possible in an acceptable time.
2. In integrated approach, whenever model parameters change due to the disorders caused by internal or external manufacturing system, the planning problem should be solved once again. Whereas in HPP approach, these random events are gradually absorbed and considered without any requirement to solve all sub problems. It can be modified with some calculation efforts appropriated to influence of the mentioned events on planning problem.
3. High levels in hierarchical structure use broad and aggregate demand information. This aggregate forecasting are more accurate and simply to calculate than detailed forecasts which are used in an integrated model. Therefore, long term plans in hierarchical approach are more accurate than long term plans in integrated models.
4. There is possibility of using proper decision making criteria in different levels of hierarchical structure. In industrial applications, different criteria use in different management levels. For example, worker hire/layoff costs are usually considered in long term planning level and start up costs are known for scheduling level.
5. In the lowest level of hierarchical approach, decisions for each workshop plant planning (operational planning) are usually performed by workshop people. Higher levels of decision making for a factory or a department are made in the proper levels of management hierarchical structure. This relationship between management hierarchical structure and planning will be lead to management and organization improvement.
6. One of the advantage characteristic of HPP comparing with integrated approach is to have a feedback from lower levels to the higher levels for updating input parameters. In rolling horizon approach, higher levels models are again solved by using new information that is generated from of lower levels. Then outcomes of higher levels are applied as constraints for lower levels. In this way production system will have the required ability and flexibility to repel internal and external changes.

In previous studies for PS, there is very little attention to the hierarchical structure aspects of PS production planning. Also in previous studies there are missing a proper updating feedback system for increasing reliability and developing performance of the PS production planning. A feedback system allows decision makers not only to have a very flexible production plans but also to be able revise easily the model into different levels with the inputs like 'any unexpected events', 'upper manager decisions makers' and 'actual data which is gained with time lapse'. Moreover in the previous studies, objective functions are used in PS production planning models were cost based and other criteria of power production as environmental pollution, proportion of total capacity and so on, were not considered with economic criterion together.

The main purpose of this paper is to improve the performance of the PS generation planning structure practically. A feedback system of FHPP is applied with multi objective functions for power production planning. The imprecise input parameters along with some soft constraints are introduced in the model formulation instead of using the crisp data and imposing hard constraints for providing required consistency between decisions of different levels. The result of production plans through FHPP would be more feasible and compatible in practice.

The rest of the paper is organized as follows: The relevant literature is presented in Section 2. The overall structure of the proposed FHPP model along with the corresponding fuzzy mathematical models is illustrated in Section 3. In Section 4, the proposed fuzzy HPP structure is elaborated applying appropriate strategies and the associated fuzzy linear programming models are converted into the equivalent auxiliary crisp models. The proposed FHPP structure is implemented for a real PS in Iran. The case study and the obtained results as well as some managerial implications are provided in Section 5. There is indicated that applying FHPP as a new approach for PPGP, will conducted toward effective structured and efficient PS as concluding remarks in Section 6.

2. Background

Based on the main characteristics of the research problem, explained in more details in the next section, the most relevant and recent literature in three different but somewhat close streams of: 1 – production planning in Power Systems, 2 – application of mathematical optimization (algorithmic) methods in PS production planning problems and 3 – applications of fuzzy modeling in production planning are studied.

2.1. Production planning in PS

The long-term problem is a well-known stochastic optimization problem, as several of its parameters are only known as probability