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A non-linear programming model for optimization of the electrical energy consumption in typical factory

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Abstract

In this paper a non-linear programming model is developed for a typical factory which presents the optimal values and times for the electrical energy consumption based on doing activities and operations in factory. Model's appropriate parameters are been with due attention to define tariffs and limitations by distributions of electrical energy. Furthermore, the operational constraints of the typical factory are formulated and these constraints are merged with the constraints of appropriate consumption.

Keywords: Load curve; Non-linear programming; Electrical energy consumption; Optimization; Factory; Trapezium method

1. Introduction

High energy consumption as well as reducing the known energy resources is the key factors to develop the philosophy of optimum energy consumption. So with representing different energy optimization methods and ways it is quite possible to reduce the energy consumption (optimum consumption) because the number of energy consumers versus the energy resources and even energy production and a conversion facility is increasing everyday.

Electrical energy is also involved with the same problem, so optimizing energy production and consumption methods in this field looks quite necessary particularly in domestic section, plants and factories, and so on. This can be discussed as a linear or a non-linear optimization issue, but many researchers tend to use the linear assumptions to simplify the issue. Then it is possible to treat the problem as an integer linear planning issue [1].

Load management [2–5] is the process of scheduling the loads to reduce the electric energy consumption and or the maximum demand. It is basically optimizing the processes/loads to improve the system load factor. Load management procedures involve changes to equipment and/or consumption patterns on the customer side. There are many methods of load management which can be followed by an industry or a utility, such

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as load shedding and restoring, load shifting, power wheeling, installing energy-efficient processes and equipment, energy storage devices, co-generation and non-conventional sources of energy, and reactive power-control [6]. To encourage load shifting in industries, and thereby to reduce peak demand, many utilities have already implemented time of use rates (TOU) or have plans for introducing such rates [5].

In other hand, load management [2–5] in power systems will in general depend on the organizational structure of the industry and the individual utilities economic environment and internal structure. If a company has own generation with a certain mixture of, say, thermal units, gas turbines and hydro power stations, its load management policies must generally be different from a utility with no generation but purchasing entire energy from a bulk supplier based on a certain contract or tariff. In the first case the cost structure of the company's different generation facilities will affect the possible savings by curtailing the loads of selected customers. In the second case it is the structure of the tariff which signals the possibilities of savings by load curtailment. This can be discussed as a linear or a non-linear optimization issue, but many researchers tend to use the linear assumptions to simplify the issue. Then it is possible to treat the problem as an integer linear planning issue [1] or fuzzy models [7,8].

Reviewing the last year related essays shows an intention to use complement algorithms as a solution for this problem, which has also had some good results [1,6,9].

The distribution system planning goal is to assure that a demand growth can be satisfied in an optimal way from the secondary feeders to the substations from where energy must be delivered to the final client economically while complying with several technical specifications. These considerations can harden the problem of optimal planning calculus. The people in charge of distribution planning should consider the energy consumption, their geographical location, laws regarding the use of soil plus other aspects to come up with the substations dimensioning and location, the maximum efficiency routes, while minimizing the energy loss in the feeders and deployment costs, plus satisfying the reliability of service constraints.

The design of electric energy distribution system planning is executed around the existing system using a procedure containing the following steps: demand forecasting and assignment to existing or new areas, location and dimensioning of substations, dimensioning and routing of feeders and distribution networks. Today, and thanks to the computers development, improvements to the proposed plans can be obtained analyzing several different alternatives by using mathematical models and different optimization procedures.

The problem could be naturally seen as a non-linear combinatorial optimization problem, but many researchers use linear approximations to reduce the problem. Then, the problem can be seen as a mixed integer linear programming problem and solved using the available procedures based on the simplex method. Many researchers use a dynamic programming model and some of them use graph theory related models, and solve the problem combining shortest path algorithms and transportation algorithms. It's interesting to remark that many of the revised models used for practical problems use employ Branch and Bound algorithm as their solution. In the reviewed papers from the last years, there is a tendency to use evolutionary algorithms and expert systems as solution procedures, obtain which have achieved good results with these techniques [10,11].

The objectives of this paper are as follows:

- developing a non-linear programming model for a typical factory,
- presenting the optimal values and times for the electrical energy consumption based on doing activities and operations in factory,
- attention to define tariffs and limitations by distributions of electrical energy,
- formulating the operational constraints of the typical factory and merging these constraints with the constraints of appropriate consumption.

According to the above-mentioned items, the structure of the paper is as follows: in Section 2, the modeling of load curve's improvement in typical factory is presented. The notations and variables that are used in mathematical model are determined in Section 2.1. The constraints of the model are presented in Section 2.2. The goal function for the model is represented in Section 2.3 and the total mathematical model is presented in Section 2.4. Section 3 presents and discusses the numerical test and results of the model. Finally, Section 4 highlights the conclusions of the paper.