TITLE:
Power plant preventive maintenance scheduling problem: a 0/1 mixed integer linear programming approach based on cost and reliability to establish an effective policy

Keywords: Preventive maintenance, Power plant, Cost optimization

Topic(s): Operations Planning, Scheduling and Control, Reliability and Maintenance

Word count: 985

Purpose
This paper addresses the Power Plant Preventive Maintenance Scheduling Problem. The problem is taken from the power industry, where providing electric energy to the consumers without interruption is of high importance. This problem is usually treated in the long-term exploitation of electric production systems. It requires determining the period for which generating units of an electric power utility should be taken offline for planned preventive maintenance over a time horizon, usually on a yearly basis. The objective is to minimize the total operating cost while a set of constraints is satisfied, with emphasis on realiability.

Design and methodology
The problem under study consists in disconnecting a power plant, belonging to a power system, periodically to review its functioning and to detect potential failures. A cycle is repeated over time according to Figure 1.

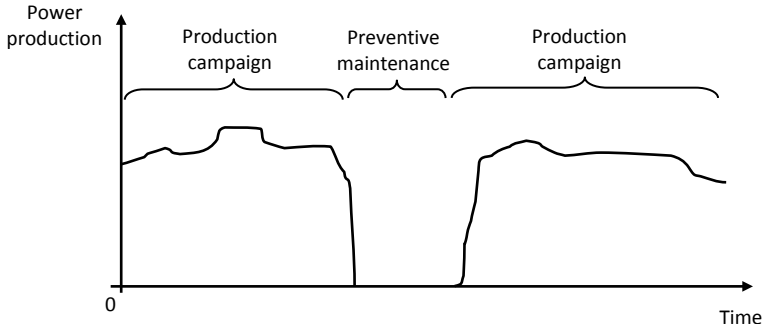

Figure 1 - Production plan for a power plant including outage for preventive maintenance

The planned maintenance activity is designed to lengthen the useful life of power plants and to maintain their safety. This strategy is a way to avoid system malfunctions and the subsequent corrective maintenance, minimizing the chance of breakdowns. Its importance emerges from the real necessity of maintaining high efficiency at a minimum cost to improve the reliability of power plants, raising their availability.

Power plants are integrated into a global electric system. For this reason, an unpredicted failure affects the rest of the system. As a consequence, an unforeseen shutdown in a power plant might hit the system by causing an undesirable interruption in the power supply, a reduction in the quality service, and subsequent customer dissatisfaction. In view of these reasons, the PPPMSP is a very important topic to evaluate.

Typically, the PPPMSP is categorized as a 0/1 mixed integer linear programming problem. Its complexity is the primary challenge that must be addressed and arises from the enormous size of the system to be modelled. A large number of variables are present in the formulation, especially considering the binary variables, which are the most difficult to handle.

The mathematical formulation of the problem is established according to a complex optimization problem under the perspective of a 0/1 mixed integer linear programming scheme In compliance with the objective function and the constraints, the problem is modelled in the following qualitative form:

Minimize *Costs*
subject to *Constraints (maintenance, operation, generating volume and wind power)*

Five types of costs are considered: fixed cost; start-up cost; shut-down cost; production cost; and maintenance cost.

The constraints of the problem are divided into five main groups: maintenance constraints; production operation constraints; maintenance and connection constraints; generating and volume constraints; and wind power generation constraints.

The resolution involves the use of an optimizer (GAMS) as shown in Figure 2:

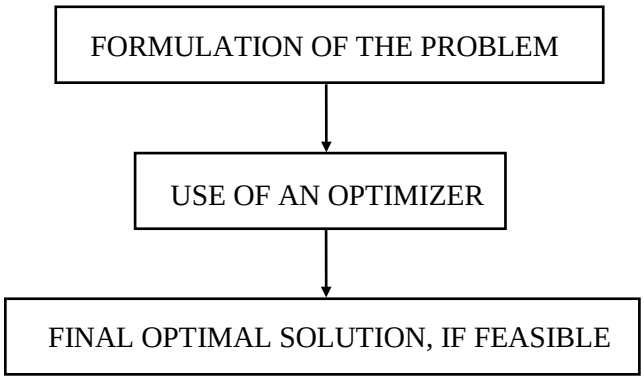

Figure 2 - Procedure for the solving process

Findings

A realistic application example is included to validate the model and the methodology proposed. This example is based on the Spanish power system.

After running the model for the application example and using the abovementioned optimizer, the findings obtained are:

- Objective function in terms of cost
- Maintenance schedule over the time horizon
- Power produced by every power plant
- Cost associated with every power plant
- Computational time

Conclusions

The main conclusions of the work presented are as follows:

- Several costs are integrated into the model so what its efficiency is increased.
- Different types of power plants were considered, including wind, hydroelectric, thermal and nuclear power plants.
- The model designed uses a wide variety of constraints.
- Maintenance, production operation, maintenance and connection, generating volume, and wind power constraints are combined in this model.
- The results could be useful to those companies that have power production activities.
- The study can be extended to other industriles (automotive, electronics, etc.).

Contribution

The most relevant contribution of this work is to present a global approach to the PPPMSP, designing an exhaustive model based on a cost centered maintenance perspective, and achieving an optimal solution. The research performed here encompasses a wide range of power plants: thermal (coal, gas, and oil powered units), nuclear, hydroelectric, and wind power plants; and brings together the diverse sources of electricity production. In addition, a complete set of constraints is included to model the real world for power systems. This structure means that the resulting model analyzed is representative of current energy production systems in many countries and regions. This model could be used by researchers and practitioners.

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