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Sensitivity analysis of technological, economic and sustainability evaluation of power plants using the analytic hierarchy process

Athanasios I. Chatzimouratidis, Petros A. Pilavachi *

Department of Engineering and Management of Energy Resources, University of Western Macedonia, 50100 Kozani, Greece

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ABSTRACT

Technological, economic and sustainability evaluation of power plants by use of the analytic hierarchy process and nine end node criteria for a reference scenario based on subjective criteria weighting has been presented in a previous paper by authors. However, criteria weight variations may substantially modify overall evaluations and rankings of power plants.

The current paper presents a sensitivity analysis with four alternative scenarios (sets of criteria weights) compared with the reference scenario. The results show that priority to "technology and sustainability" favors renewable energy power plants, while priority to "economic" criteria favors mainly nuclear power plants and less the four types of fossil fuel power plant.

1. Introduction

An integrated technological, economic and sustainability evaluation of ten types of power plants by use of the analytic hierarchy process and nine end node criteria, for a reference scenario based on subjective criteria weighting has been presented by Chatzimouratidis and Pilavachi (Chatzimouratidis and Pilavachi, 2008c). Nevertheless, criteria weight variations, due to different decision makers may lead to significant alterations in the overall evaluation and ranking of ten types of power plant.

Especially, when assessments are subjective or there is uncertainty, many different possible cases should be evaluated (Ozdemir and Saaty, 2006). Therefore, sensitivity analysis is an useful tool used to analyze several aspects of the energy sector like economic policies for greenhouse gas emissions reduction (Georgopoulou et al., 2006), climate alteration due to power generation (Zwaan and Gerlagh, 2006) and power plant technology and economics (Hamed et al., 2006). Sensitivity analysis has also been applied for the analysis of power plant impact on the living standard using the analytic hierarchy process (Chatzimouratidis and Pilavachi, 2007, 2008a, b). Alternate scenarios have been widely applied in the energy sector (Costantini et al., 2007; Diakoulaki and Karangelis, 2007; Ghanadan and Koomey, 2005; Trevisani et al., 2006).

Sensitivity analysis can be applied to several levels of the energy sector. For example, it was applied to a certain element of power plant operation like nuclear safety (Marseguerra et al., 2005), a power plant type like a small hydro power plant (Kaldellis et al., 2005) or even to power plant operation and management in a deregulated market (Carraretto, 2006). Moreover, the analytic hierarchy process and sensitivity analysis has been proven to be a useful tool for analyzing a wide range of problems, such as hospital selection (Wu et al., 2007) or bankruptcy prediction (Park and Han, 2002).

This study presents a sensitivity analysis comprising of four alternative scenarios covering different sets of criteria weights, which are compared with the reference scenario. Before applying sensitivity analysis, the reference scenario is presented and overall score and ranking is carried out according to this scenario. Sensitivity analysis describes alterations of scores and rankings according to variations of criteria weights with regard to this scenario.

Average values based on reliable international literature and organizations were used for power plant evaluation against end node criteria. Nevertheless, different criteria weights incorporated in the sensitivity analysis can compensate for possible variations of such values. The number of cases examined should be the smaller one to give the most complete information on scores, rankings and tendencies of power plants to the decision maker, without confusing him.

2. Power plant evaluation overview

Technological, economic and sustainability evaluation of power plants using the analytic hierarchy process analyzed ten types of power plant under twelve criteria structured in the hierarchy tree presented in Fig. 1. Nine out of twelve are end node criteria, which are criteria that are not further divided in

* Corresponding author. Tel.: +30 2461056640; fax: +30 2461056641.
E-mail address: ppilavachi@uowm.gr (P.A. Pilavachi).

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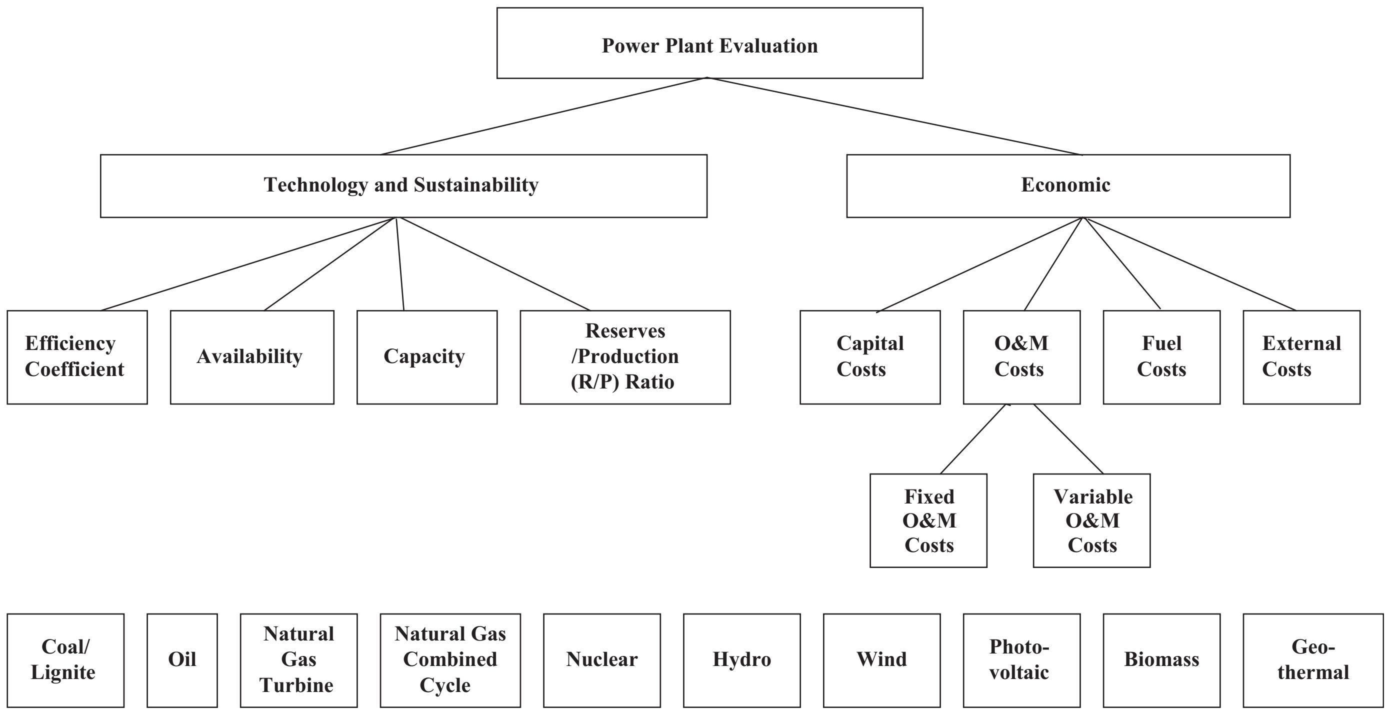

Fig. 1. The hierarchy tree for optimization of technological, economic and sustainability criteria of the 10 types of power plant.

Table 1
Local criteria and subcriteria weights.

Power plant evaluation (100%)								
Technology and sustainability (75%)				Economic (25%)				
Efficiency coefficient (10.56%)	Availability (10.56%)	Capacity (4.84%)	Reserves-to-Production ratio (74.04%)	Capital costs (38.99%)	O&M costs (6.79%)		Fuel costs (38.99%)	External costs (15.23%)
					Fixed (16.67%)	Variable (83.33%)		

Table 2
Global criteria and subcriteria weights.

Power plant evaluation (100%)								
Technology and sustainability (75%)				Economic (25%)				
Efficiency coefficient (7.92%)	Availability (7.92%)	Capacity (3.63%)	Reserves-to-Production ratio (55.53%)	Capital costs (9.75%)	O&M costs (1.70%)		Fuel costs (9.75%)	External costs (3.80%)
					Fixed (0.28%)	Variable (1.42%)		

subsequent levels of the hierarchy tree. Power plants are evaluated against the nine end node criteria, while non-end node criteria in the upper levels of the hierarchy tree (“Technology and Sustainability”, “Economic”, “O&M Costs”) are evaluated as a result of the synthesis of their subcriteria. At the top level of the hierarchy tree the goal is presented, i.e. power plant evaluation. Levels two, three and four consist of the criteria and subcriteria against which the ten types of power plant presented in the fifth level are evaluated.

Table 1 presents the global criteria and subcriteria weights, i.e. the percentage contribution of each of them to the overall score of each type of power plant. Table 2 presents the local criteria and subcriteria weights, which are the percentage contribution of each of them with respect to their parent node. For example, capital costs have 9.75% global weight, which is its weight contribution to the overall score or the goal. On the other hand, its local weight is 38.99% with respect to its parent node, which is the economic, i.e. its weight contribution to the “economic” score.

In order to perform a sensitivity analysis, both criteria weighting and power plant scoring against end node subcriteria should be available. A bottom-up synthesis can then provide the scoring of subcriteria and criteria in the upper levels of the hierarchy tree. Tables 3 and 4 present a detailed analysis of the results grouped by end node criteria or a type of power plant. These are the reference results that construct the reference scenario on which sensitivity analysis will be applied.