# Multiobjective energy purchase strategy with an evolutionary algorithm.

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**Abstract**

An electric market is generally composed of generating units, wholesalers and retailers. The wholesalers, usually owners of generating units, are interested in the economical dispatch of energy. On the other side, the retailers, are interested in acquiring the energy at the lowest possible price and deliver this energy to the costumers in a safe way. This paper proposes a multiobjective approach to the retailer’s energy purchase strategy problem. An implementation of the recognized Strength Pareto Evolutionary Algorithm 2, SPEA2, is described. To validate the proposed method, this work uses real data from the Paraguayan retailer, ANDE. Experimental results show a promising performance of the proposed method.

**Key Word**: Multiobjective Evolutionary Algorithm, Electric market, *Strength Pareto Evolutionary Algorithm* 2 (*SPEA2*).

## Introduction

The price, an energy retailer charges to the final consumer, depends directly on the price it purchased the energy from the wholesalers [1]. Therefore, if a retailer is able to acquire energy at the lowest price, providing at the same time a good quality service, it could charge a lower price to the consumer gaining competitiveness [2]. The Paraguayan system receives energy from three hydro power plants, Acaray, Yacyreta and Itaipu. Acaray is owned by Paraguayan government retailer, ANDE [3], so it is consider as fixed maintenance cost. Yacyreta is a Paraguayan-Argentinean bi-national enterprise that sells energy to ANDE at a determinate price per KWh. Itaipu is a Paraguayan-Brazilian enterprise which sells load by long term contracts; i.e., ANDE contracts the load it will need beforehand. Itaipu only sells a predetermined amount of energy by contract; this is the energy it will generate with a high probability. But depending on the river condition and maintenance schedule it can, and usually does, generate more energy than it sold by load contracts. This energy surplus is sold, at a very low price to Paraguay and Brazil, but Itaipu can not assure the availability of this energy [4]. For this reason, making a lower load contract with Itaipu and using more energy surplus will yield a lower energy cost to the retailer but with a higher risk.

## Multiobjective optimization

A general Multiobjective Optimization Problem (MOP) includes a set of *n* decision variables, *k* objective functions, and *m* restrictions. Objective functions and restrictions are functions of decision variables. This can be expressed as [5]:

Optimize $y = f(\mathbf{x}) = (f_1(x), f_2(x), ..., f_k(x))$

Subject to $e(\mathbf{x}) = (e_1(x), e_2(x), ... ,e_m(x)) \geq 0$

where $\mathbf{x} = (x_1, x_2, ..., x_n)$

To compare two solutions in a multiobjective context, the concept of Pareto Dominance is used. Given two solution, **u** and **v**, **u** dominates **v,** denoted $\mathbf{u} \succ \mathbf{v}$ , iff f(**u**) is better or equal to f(**v**) in all objective functions and strictly better in at least one objective. If **u** does not dominate **v** and **v** does not dominate **v**, **u** and **v** are not comparable ($\mathbf{u} \sim \mathbf{v}$).

A decision vector **x** is non-dominated with respect to a set V, iff **x** is not dominated by any member of V. The set of non-dominated solutions of the whole set of feasible solutions is known as Optimal Pareto set. The corresponding set of objective vectors constitutes the Optimal Pareto Front.

## Problem formulation

The following assumptions were made for this work, the demand is predictive without randomness and no eventualities are contemplated. Considering this, four objective functions were selected: (1) the minimization of the energy purchase cost, (2) minimization of the energy not supplied as a consequence of Itaipu’s surplus randomness, (3) minimization of system voltage deviation and (4) the minimization of equipments overload. Actually, there are some procedures that allow Brazil and Paraguay to support each other with Itaipu energy in case energy contract and energy surplus are insufficient to satisfy the demand. Thus, normally there will not be energy not supplied to costumers. However, for this paper, the energy not supplied can be seen as a measure of the solution risk.

SPEA2 algorithm [6] was modified for the problem in study. An external archive was created to save all non-dominated solutions generated during the algorithm execution. This prevents the Pareto front degradation, i.e., solutions join the archive even when these are dominated by other solutions previously eliminated by a truncation procedure. Another modification is the inclusion of two crossover operators, the traditional one and an operator specially designed for this work that emphasizes the search of low cost solutions.

## Experimental results

Test case: The Paraguayan transmission system is used to validate the proposed algorithm. It has 67 buses, 70 transmission lines and 20 power transformers [3]. It has three main generation point, the hydro power plants of Acaray, Yacyreta and Itaipu. Considering that the load contracts with Itaipu are signed on monthly bases, the period of time considered for the test is a typical month, specifically January of 2006 for the reported experimental results.

Bearing in mind that small voltage deviations are acceptable, the third objective function actually minimizes a penalty given to buses with voltage deviations larger than an acceptable maximum. Reported results penalize only voltage deviations larger than 0,1 p.u. Ten executions of the proposed method and the traditional SPEA2 were run. Figure 1 presents the results in a graph of cost vs. energy not supplied where solutions with similar voltage deviation penalties are shown with the same color (mark). Figure 1 presents solutions with a cost lower than 16.5 million dollar because more expensive solutions are economically unacceptable. Figure 1 also shows that the proposed algorithm generated several solutions of price similar (or even cheaper) than the purchase option implemented by ANDE in January 2006, i.e. 14.5 million dollars [3].

To compare the set of solutions found by the proposed method, $FP_m$, and the set generated using SPEA2, $FP_s$, the coverage metric [4] was used. The coverage of set A over set B, ***C***(A,B) indicates the proportion of B´s solutions that are dominated by at least one solution of set A. The value of $C(FP_m, FP_s)$ is 0,222 and ***C*** $(FP_s, FP_m)$ is cero. This clearly indicates than none of the solutions found by the proposed method was dominated by any solution generated by traditional SPEA2. On the other side, more than 22,2 % of solutions in FPs are dominated by a least a solution in $FP_m$.

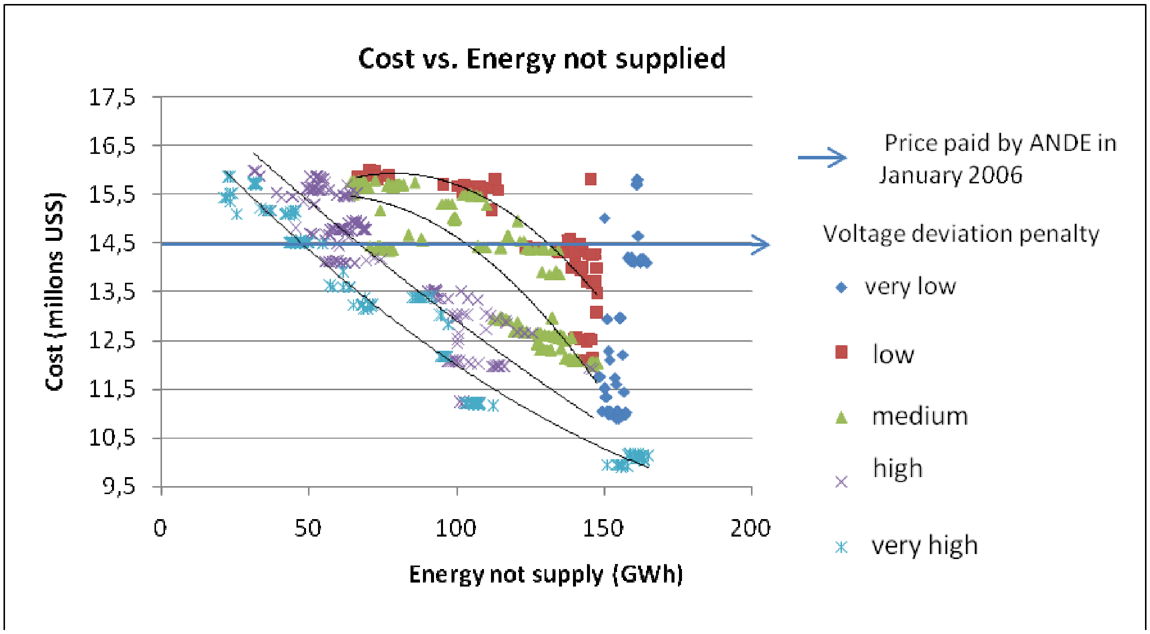


Figure 1: Cost of solutions vs. energy not supplied, solutions with similar voltage deviation penalties are shown with the same market. The price paid by ANDE is highlighted.

**Conclusions**

The most important contribution of this paper is a methodology for the generation of good solutions for the multiobjective energy purchase strategy problem. The present work used real data from the Paraguayan electric retailer, ANDE. Another contribution of this paper is the design of a special crossover which searches for lower cost solutions. Observing the experimental results, it can be concluded that the proposed method can offer good solutions to the problem in study. This is, the algorithm generates a larger number of low cost solutions than traditional SPEA2. Besides, its solutions cover a wide range of the solution space with a good spread, considering all objective functions. It is remarkable than the proposed method found a large number of solutions with cost value comparable to, or lower than, the energy purchase strategy implemented by ANDE.

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