A FUZZY DYNAMIC PROGRAMMING APPROACH FOR EVALUATION OF EXPANSION DISTRIBUTION COST IN UNCERTAINTY ENVIRONMENTS

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***Abstract*— This paper presents a new Fuzzy Dynamic Programming model that calculates the optimum solution of problems with uncertainties in data defined by fuzzy sets. The result includes the determination of an Intrinsic Risk Threshold of the solution. Extrinsic Risk Thresholds may also be set by a Decision Maker, in order to obtain more robust solutions. The technique is applied to the calculation of Distribution System expansion costs to serve the objectives of a Regulatory Authority (Regulator) in fixing levels of efficiency, targets and penalties to a regulated market.**

***Keywords*— Distribution Planning; Fuzzy Dynamic Programming; Risk Analysis, Risk Threshold, Fuzzy Regret.**

I. INTRODUCTION

Distribution expansion planning is no longer an activity that only interests utilities. In a market environment, where several actors may participate or contribute to the evolution of distribution systems, regulators have the need to evaluate the impacts and costs of this evolution, too.

This is especially relevant when the regulator wishes to define a theoretical case for distribution expansion costs, in order to be able to compare the actual performance of an utility with such reference - this may allow the establishment of efficiency measures that may have consequences on the rewards allowed to the distribution utilities, on the assessment of added costs induced by external factors or in fixing penalties.

However, the definition of a theoretically optimal expansion cost is not easy, not only because of the complexity of the problem but also due to the level of uncertainties present in data and in forecasts. Therefore, one must develop models in which these uncertainties are recognized and treated as such.

But the incorporation of uncertainties in a system expansion model in which decisions are sequentially made, cannot be done without considering risks associated with such decisions.

Besides, many of the uncertainties are not of probabilistic or stochastic nature and should not be represented as such - in this case, representing uncertainties by Fuzzy Sets is an alternative.

In this paper, a solution to a mid-term distribution expansion planning problem is proposed, from the perspective of a Regulator. Along several stages in time, one searches for the set of decisions (associated with investment costs – new lines, new substations - and operation costs - namely power losses) that “optimize” the global cost of system development. However, because of uncertainties (in power demand, in equipment costs) this goal cannot be achieved: depending on the instantiated values for data with uncertainty, the optimal decisions may vary.

In the work reported in this paper, the development of a distribution system is simulated, according to a Dynamic Programming principle. This simulation intends to retain the set of decisions that may be optimal in distinct scenarios, in order to seek the sequence of decisions that may display, as much as possible, a degree of immunity to uncertainties. These sets of decisions may be seen as a fuzzy trajectory through system state space. By establishing thresholds, delimiting admissible from inadmissible risk levels, one is able to control the size of the corresponding optimizing fuzzy trajectory.

This is a Risk Analysis paradigm approach - decisions are selected in order to minimize the possible regret felt, in case the future demonstrates that the decision made was not optimal. In the following sections, the model will be described and its usefulness illustrated.

II. METHODS

A. Discussing the Fuzzy Dynamic Programming

There is an algorithm in the class of Dynamic Programming (Bellman and Dreyfus, 1962), called Fuzzy Dynamic Programming, which enables the calculation of an optimum of certain problems that include uncertainties, modeled as fuzzy sets, in constraints and objective function – following the Optimality Principle of Bellman-Zadeh (1970). This principle leads to the calculation of a maximizing decision (maximizing a membership degree) over the intersection of objective and constraints.