A COMPARISON OF METAHEURISTICS ALGORITHMS FOR COMBINATORIAL OPTIMIZATION PROBLEMS. APPLICATION TO PHASE BALANCING IN ELECTRIC DISTRIBUTION SYSTEMS

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***Abstract*— Metaheuristics Algorithms are widely recognized as one of most practical approaches for Combinatorial Optimization Problems. This paper presents a comparison between two metaheuristics to solve a problem of Phase Balancing in Low Voltage Electric Distribution Systems. Among the most representative mono-objective metaheuristics, was selected Simulated Annealing, to compare with a different metaheuristic approach: Evolutionary Particle Swarm Optimization. In this work, both of them are extended to fuzzy domain to modeling a multi-objective optimization, by mean of a fuzzy fitness function. A simulation on a real system is presented, and advantages of Swarm approach are evidenced.**

***Keywords*— Metaheuristic Algorithm; Swarm Intelligence; Fuzzy Sets; Electric Distribution; Phase Balancing.**

I. INTRODUCTION

Metaheuristics Algorithms are widely recognized as one of more practical and successful approaches to solve combinatorial problems. However, the original formulations have been oriented to mono-objective optimizations. Many proposal of extensions to multi-objective domain have been established, but each formulation has showed particular advantages and limitations, in general, over certain kind of problems. Does not exist the "best multiobjective metaheuristic algorithm", but some algorithms are more appropriates for certain problems. Such is the case of Phase Balancing in Low Voltage Electric Distribution Systems (LVEDS), when a classic programming approach is not addressed to solve it. The balance is referred to the loads in the feeders of a LV network in an EDS. The classic approach, has demonstrated major limitations, as it will be discussed. For this reason, a metaheuristic approach is an alternative that may produce very good results.

This work is organized as follows: in the section II.A the problem of Phase Balancing is presented. It describe the no desired effects that produce an elevate unbalance degree in the loads of a low voltage (LV) feeder. In section II.B are described the principles of two mentioned metaheuristics: Simulated annealing (SA) and Evolutionary Particle Swarm Optimization (EPSO). In section II.C, an introduction of the static fuzzy decision is presented, and the extension of the SA and EPSO algorithms to fuzzy domain, by mean of a fuzzy fitness function, is proposed for solve multi-objective optimizations. Two models, designed as FSA and FEPSO, specialized to solve the Phase Balancing Multi-objective Problem, are obtained. Lastly, in the section II.D, a simulation on a real LV feeders system is presented and the results, obtained from FSA and FEPSO, are compared. The conclusions are presented in the section III.

II. METHODS

A. The Problem of Phase Balancing

The most LV networks of an EDS are three-phase systems, physically defined by feeders with three conductors, one per phase (feeders system). If all loads of each conductor-phase were three-phase (with the same value in each phase) then the system would be balanced. However, feeders loads in a LV network, for low incomes residential areas, are commonly single-phase. Original feeders system design, depends on accuracy of the given load data and, even maximizing this accuracy, there will always be certain unbalance degree, due to single-phase loads. A high unbalance degree, produces high voltage drops, high power and energy losses and low reliability. For this reason, such degree must be as low as possible. For the purpose of this paper, LV feeders system will have only single-phase loads. A formulation to the general problem of Phase Balancing, in this context, can be expressed as follows:

$$Min\ \{ Loss_T\ ;\ I(\Delta u)\ ;\ |I_{[o]}|_f \} \quad (1)$$

Subject to:

$$|I_{[R]}|_f \leq I_{Max} \quad (2)$$

$$|I_{[S]}|_f \leq I_{Max} \quad (3)$$

$$|I_{[T]}|_f \leq I_{Max} \quad (4)$$

where the subindex *f*, refers to the output of substation connected to the principal feeder of the system; $Loss_T$ are the total active power loss of system and $I(\Delta u)$ is an index that depends on voltage drops.