OMAP (Organizational Memory Aided Planning): An Integrated Planning Tool Using Concepts of Knowledge Management and Multi-Objective Optimization

Carlos C. B. OLIVEIRA
DAIMON – Brazil
barioni@daimon.com.br

André MEFFE
DAIMON – Brazil
andre.meffe@daimon.com.br

Dário TAKAHATA
DAIMON – Brazil
dario@daimon.com.br

Paulo H. BAUMANN
DAIMON – Brazil
paulo@daimon.com.br

Rubens L. MARCONDES
DAIMON – Brazil
rubens.marcondes@daimon.com.br

Ricardo H. GUEMBAROVSKI
CELESC – Brazil
ricardohg@celesc.com.br

Neissan ALENCASTRO
CELESC – Brazil
neissan@celesc.com.br

Diego C. S. PRADO
CELESC – Brazil
diegocsp@celesc.com.br

ABSTRACT

This paper presents the methodology and its correspondent software, which has resulted from a R&D project carried out by Daimon Engineering and CELESC Distribution. The result of this partnership has been the development of a Decision Support System (DSS) which concatenates the use of Knowledge Management for the promotion of organizational memory of the utility´s Medium Voltage Distribution Planning (MVDS) and the usage of a multi-criteria decision making theory based on an evolutionary algorithm. The former is based on the use of taxonomies which identify possible solutions (works) based on past experiences for future evaluation (after the work completion). These markings from taxonomies provide the retrieval of the good solutions used by employees in past situations, promoting the perpetuation of good practice. The latter employs a priori or a posteriori approach in terms of preference articulation for solving multi-objective problems. Therefore, these two combined modules have been implemented in the same software (OMAP) to rescue past similar solutions and to optimize the alternatives (works) quality.

INTRODUCTION

CELESC is a state-owned electric distribution utility, located in the southern region of Brazil which supplies approximately 2,700,000 customers (around 6,700,000 inhabitants), in the state of Santa Catarina, in Brazil. The concession area of CELESC covers 92% of the state of Santa Catarina (257 out of 293 cities), divided into 16 Regional Agencies, which meet the market of Santa Catarina.

In order to meet the quality standards and the technical criteria prescribed by the Brazilian Electricity Regulatory Agency (ANEEL), CELESC has been improving its distribution service by means of propositions of expansion and improvement works.

However, due to the large amount of work requested by the 16 CELESC´s Regional Agencies, and also due to the restriction of resources available for the execution of these works, CELESC has not been able to meet all requests.

OBJECTIVES

This paper presents a methodology and its correspondent computer programme based on concepts of Knowledge Management which will keep CELESC´s organization memory (destined to improve the input data) accessible to future users and engineers of the Planning area of CELESC), along with another tool, based on a multi-objective optimization methodology which primarily yields a MV work plan (destined to improve the output data).

Therefore, the former helps the user to choose the solution through the usage of concepts of Knowledge Management, enhancing the input data, i.e. retrieving the organizational memory of CELESC, in order to suggest solutions, according to the type of electrical system, besides the type and cause of problems involved.

On the other hand, the latter will optimize a works list based on the set of propositions made by each Regional Agency of CELESC, in order to resolve each one of the proposed problems in terms of voltage drops, overcapacity of feeders and reliability issues. Those works proposals are then forwarded to the Planning Central Agency of CELESC, where the best alternatives are chosen. Thus, the software produces an optimal list of works on which the technical, economical and other relevant aspects are contemplated.

METHODOLOGY

Knowledge Management

Introduction

With the aim of improving the entire Planning process of CELESC, from the works proposition until the selection of them, a certain dispersion of the results obtained by the executed works in previous years has been observed, not by lack of registration, but for missing a management tool that concentrated and retrieved the information of the various departments involved (Planning, Execution and Inspection of Works). This would facilitate the compliance of the works and the identification of the good and the bad practices. One notes that the lack of a corporate tool based, for example, on Knowledge Management limits the spread of good practice and avoids the repetition of bad practices. Currently, however, Knowledge is shared among just a few people and it is often not formalized in a corporate tool, which makes it very vulnerable to being lost due to retirement, employee relocation, etc.

The lack of such detailed and documented information in a corporate layer of open access, may also result in biased and inaccurate conclusions, as there is no comparison factor regarding their solutions and also because there is no benchmark.

Knowledge

Knowledge can be defined as something that cannot be fully structured (intangible), impossible to be completely captured and have its Logic dissected or unstructured. It is present, above all, in the minds of humans and only materializes when used or formalized. The greater the knowledge of a person, the richer and more efficient is his/her capacity on the appreciation and analysis of data and information available. Consequently, the quality of the decisions made during his/her daily routine will be better [1].

According to [2], there is an important distinction between two types of Knowledge, which has been widely used and allows a practical way of addressing the issue:

• Explicit Knowledge: It refers to the transferable knowledge in formal and systematic language. This is the structured knowledge and is capable of being verbalized. Therefore, this is the part of the structured knowledge which may be stored, transported and shared by means of documents and computer systems.

• Tacit Knowledge: It is personal, specific to a certain context and thus, difficult to be formulated and communicated. It is the knowledge inherent to the people, that is, the skills he/she possesses. It is, therefore, the unstructured part of the knowledge, which cannot be formally registered or transmitted to others.

Taxonomy

Taxonomy is not a recent concept as it sounds. The Swedish scientist Karl von Linnée used this concept in the eighteenth century, during the great expansion of Natural History. The Linnée taxonomy classifies living things in a hierarchy based on their characteristics in common, starting with the kingdoms, which in turn are divided into phyla. These are divided into classes, then into orders, families, genera and species.

Within the context of Knowledge Management, Taxonomy is a useful organizing tool to Knowledge storing. Such tool (taxonomy) is essential so as the search and location of information be possible.

Multi-objective Optimization Methodology for Works Selection

The works selection problem is a combinatorial problem that might be summarized in a simplified knapsack problem type 01 (without repetition). It is noteworthy that the knapsack problem aims to maximize objective functions by optimizing the chosen items, whose sum of their weights does not exceed the capacity of the backpack restriction. One notes that the knapsack problem is analogous to the problem of selection of works on which one seeks to select works that result in the maximization of objective functions subject to a certain budget constraint.

Maximizing several dimensions simultaneously characterizes a genuinely multi-objective problem, since it is not possible to establish relative preference among the analyzed dimensions due to existing tradeoff of the goals. Thus, the objective functions involved in the work of the selection process are in a multidimensional problem that should be analyzed simultaneously. This type of solution is also known as a posteriori approach on which the decision maker articulates their preferences after running the solutions search algorithm.

One knows that the knapsack problem type 01 is very close to the codification of evolutionary algorithms. Additionally, evolutionary algorithms are state of the art in solving multi-objective problems with a posteriori approach. These facts have corroborated for choosing the Genetic Algorithm to solve this Multi-Objective Optimization Problem (MOOP).

Genetic Algorithm

The algorithm used to solve the work selection problem has been based on NSGA-II (Non-Sorting Genetic Algorithm), developed by [3], and all operators of them have been used, as follows:

- Population Generation;
- Selection;
- Dominance;
- Elitism;
- Crowding Distance;
- Tournament;
- Crossing Over and
- Mutation.

Figure 1 presents the generation, selection and elitism processes of NSGA-II methodology.

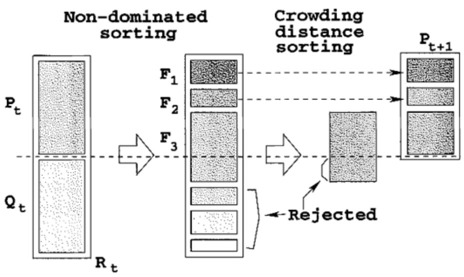

Figure 1 - Generation, selection and elitism processes of NSGA-II methodology [3]

A Priori Approach of Preference Articulation

From the 1970s the first multi-criteria decision support methods emerged, which differed from the previous mono-objective optimization paradigm in the following points:
• Use more than one criterion for the decision;
• Allow to include uncertainties in their modelling;
• Subjectivity of the decision maker is important, as there is no optimal solution, but a set of possible solutions.

A multi-criteria decision study can be defined, according to [4], by the following characteristics:
• A finite or infinite number of solutions;
• At least two criteria;
• At least one decision maker.
The multi-criteria methods can be divided into two large schools [5-6] according to the literature: North American School – Multi-Criteria Decision Making (MCDM) - and European School – Multi-Criteria Decision Analysis (MCDA). The main methodologies of the North American School are:
• Analytic Hierarchy Process (AHP) proposed by Saaty in 1970 [7];
• Analytic Network Process (ANP) proposed by Saaty in 1996 [7];
• Multiple Attribute Utility Theory (MAUT) [8];
• Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) [9].

The MACBETH methodology of the North American School has been adopted for the development of the software OMAP. Thus, an objective approach to the problem has been proposed in a similar way to the mono-objective problems. The school is based on a theory that assures the existence of functions (utility functions) capable of numerically representing the judgments of the decision maker.

The problem is described mathematically in a complete way, so that there is a clear optimal solution, for example, by aggregating decision criteria into a single objective function. The decision-maker, therefore, influences the decision objectively, choosing analysis variables and assigning notes (weights).

A Posteriori Approach of Preference Articulation

The a posteriori approach of preference articulation of multi-objective problems seeks, initially, the search for feasible solutions that are closer to the Pareto Optimal Frontier. It should be pointed out that unlike a single-objective problem in which there is an optimal solution, the multi-objective problem has as a result, a set of solutions, and there is no way to establish the best one, since to improve an indicator there will be a counterpart which will worsen another one. The compromise idea among the indicators in an a posteriori approach of preference articulation leads the multi-objective problem to have several feasible solutions.

Due to the combinatorial nature of multi-objective problems, the analytical determination and the exploration of all combinations become impractical, requiring the use of computer optimization tools to find solutions that are closer to the Pareto Frontier.

Figure 2 shows an example of Pareto Frontier and the set of solutions delimited by it.

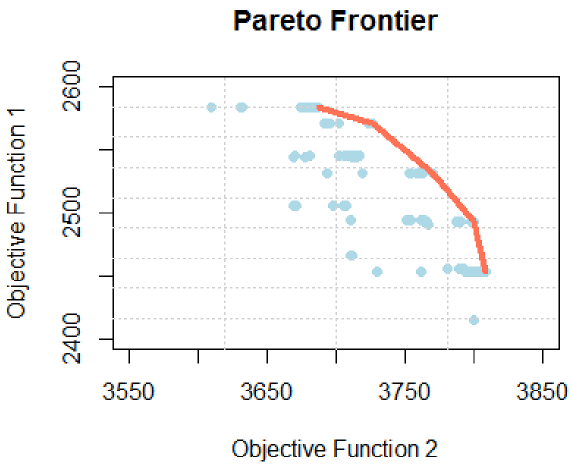

Figure 2 - Pareto Frontier and the set of solutions

Figure 3 presents an example of the arrangement of solutions after running the optimization algorithm. The solutions have been divided into layers. Thus, the solutions search boundary will be the optimized solutions whose distance to the Pareto Frontier is minimal. Only after determining that set of boundary solutions, the decision maker will articulate his/her preferences for choosing the solution that best meet his/her expectations (best compromise solution).

One should observe that the decision maker´s experience is essential in this job because it is not possible to choose, analytically, the best solution due to the existing tradeoff among the multi-objective function criteria.

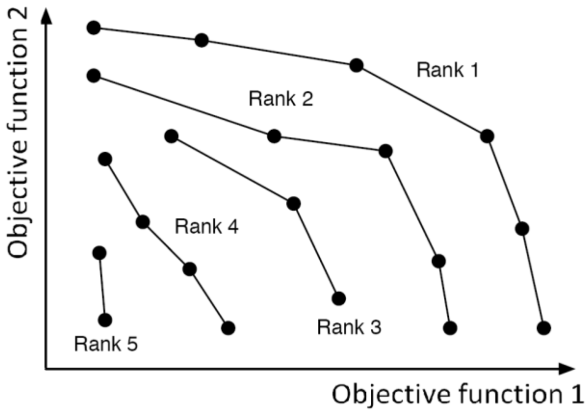

Figure 3 - Distribution of solutions after running the optimization algorithm

One can attribute, in a simple way, two primary goals to the multi-objective problems in an a posteriori approach:

• Find a set of solutions that is as close as possible to the Pareto Frontier. This is the goal one wants to meet the optimization condition of the found solutions;
• Find solutions along the full extent of Pareto Frontier that have great genetic variety. This is desirable so that the solutions are not biased or have trends for a given objective function, as this will not influence the decision maker.

RESULTS

Knowledge Management: Taxonomies

After an intense series of discussions among the members of CELESC and Daimon Engineering, a set of four taxonomies has been produced to characterize/label the whole set of issues regarding the MV systems as follows:

Electric Systems
It is divided in 9 sub-categories: Urbanization level, environment, substation, distribution network, equipment, related studies to the equipment, problem range, load and special clients.

Problem
It is divided in 2 sub-categories: Supply and customer service.

Cause
It is divided in 2 sub-categories: Controllable and not controllable.

Solution
It is divided in 2 sub-categories: Investment and operational management.

It should be pointed out that in some cases, the taxonomy has gone down to the 5th layer and all these taxonomies have been created by Daimon and CELESC technical teams, including the final amount of taxonomies and the amount of ideal layers (how deep one would go down on a certain taxonomy). Thus, any type of problem and its respective solution might be tagged, so that it would be possible to keep this information available for future consultation.

Multi-Objective Works Selection Tool

A Priori Preference Articulation Optimization Methodology

In order to compare the efficiency of the algorithm, Table I presents a comparison of the works that have been chosen by CELESC´s Regional Agencies to compose the 2015 Plan of Works and the one proposed by OMAP.

Table I - Works Plan proposed by CELESC in 2015 (on the left) and Works Plan proposed by OMAP (on the right)

Regional Agency	CELESC´s 2015 Works Plan (US$)	Works	OMAP´s Works Plan (US$)	Works
1	42,424	1	634,848	4
2	60,606	1	0	0
3	0	0	90,909	1
4	242,424	1	0	0
5	632,945	2	281,750	3
6	0	0	195,084	4
7	1,565	1	290,303	3
8	0	0	218,182	3
9	89,097	13	285,937	16
10	0	0	0	0
11	297,445	6	290,349	4
12	329,242	2	0	0
13	0	0	154,089	1
14	786,398	8	136,364	2
15	253,489	3	158,485	2
16	0	0	0	0
TOTAL	2,735,637	38	2,736,299	43

Table I above shows the works proposed for each Regional Agency and its respective resources invested in the composition of the 2015 Works Plan and the one proposed by OMAP using the a priori methodology. In both cases, the budget constraint has been kept (about US$ 2.74 million). One notes that with the same amount of resources, OMAP has proposed 5 additional works than CELESC.

A better use of the available financial resources and a better Works Plan selected by OMAP with greater technical and feeder relevance objective function values is shown in Figure 4. The former has to do with technical issues of the feeder, such as overcapacity and drop voltages. The latter takes into account the importance level of the feeder, weighing variables such as number of consumers, global market and average residential consumption of the feeder.

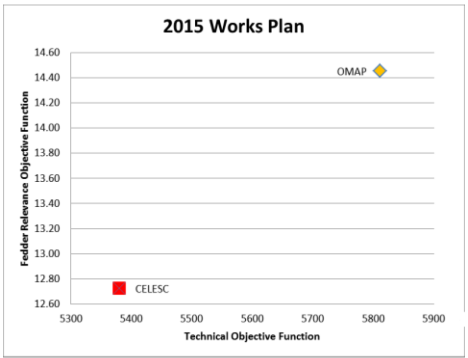

Figure 4 - Works Plan proposed by CELESC (red square) and by OMAP (yellow diamond)

A Posteriori Preference Articulation Optimization Methodology

In order to compare the efficiency of the a posteriori methodology, the Works Plans of the simulation a posteriori by the OMAP (red squares) and the one proposed by CELESC for the year 2015 are presented in Figure 5. One can notice the existence of a Pareto Frontier, where all red square points are better ranked, as by the technical objective function as by the feeders relevance objective function.

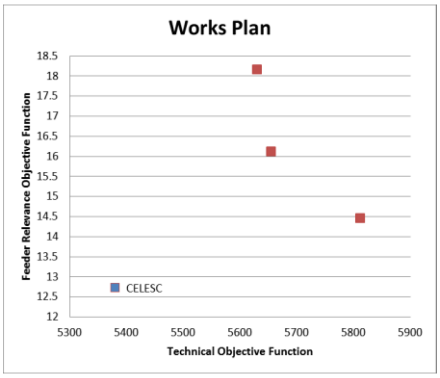

Figure 5 - Works Plan for US$ 2.74 million budget: CELESC (blue square) and OMAP (red squares)

CONCLUSIONS

This technical article presented the results of a R & D project, whose main product has been a software named OMAP which presents two modules: (a) rescue of past solutions and inferences based on similar problems to what is being analysed, and (b) elaboration of an optimized Works Plan.

The methodology developed in this project produced an optimized Works Plan through OMAP, which has been compared to CELESC´s medium voltage distribution 2015 Works Plan.

It has been possible to prove the efficiency of the algorithm, since, for the same budget constraint (US$ 2.74 million), CELESC proposed 38 works whereas OMAP, using the prioritization algorithm a priori, proposed 43 works according to Table I.

The inclusion of Knowledge Management in the electric distribution Planning process consists of a paradigm shift within the electricity industry and will provide, in the future, tangible and intangible benefits to an activity of extreme importance for the utilities. The problems imposed by the renewal of the work force can be quickly overcome with Knowledge Management through the software developed in the project.

REFERENCES

[1] AMARAL, D.C.; "Architecture for explicit knowledge management on product development processes". São Carlos, 2001, PhD Thesis – São Carlos Engineering School of São Paulo University.

[2] NONAKA, Ikujiro; TAKEUCHI, Hirotaka. "The knowledge-creating company: How Japanese companies create the dynamics of innovation", New York: Oxford University Press, 1995, pp. 284, ISBN 978-0-19-509269-1.

[3] Deb, K.; "Multi-objective optimization using evolutionary algorithms", Wiley, 2001;

[4] Figueira, J.; Greco, S,; Ehrgott, M.; "Multiple criteria decision analysis: State of the art surveys", 2005, Kluwer Academic Publishers;

[5] Baptista, M. A. P.; "A multi-criteria model to evaluate the quality system of a production environment", Florianopolis, 2000, MsC Dissertation – Santa Catarina Federal University;

[6] Roy, B. "Multi-criteria Methodology for Decision Aiding", Netherlands", 1996, Kluwer Academic Publishers;

[7] Campos, V. R.; "Multi-criteria decision aid model for the prioritization of water supply and sewage projects. São Carlos, 2011, PhD Thesis – São Carlos Engineering School of São Paulo University.

[8] Keeney, R. L.; Raiffa, H. "Decision with Multiple Objectives: Preferences and Value Tradeoffs". New York: John Wiley, 1976;

[9] Bana e Costa, C.; Stewart, T. J.; Vansnick, J. "Multi-criteria decision analysis: Some thoughts on the tutorial and discussion sessions of the ESIGMA meetings. European Journal of Operational Research, vol 99. p. 28-37, 1997.