Integrated and centralized management of electrical services in power distribution utilities

Vinícius Jaques Garcia[1], Daniel Pinheiro Bernardon[1], Maurício Sperandio[1], Cléverton do Vale[2]

[1]Federal University of Pampa, Alegrete Campus, Alegrete, Brazil
[1]{vinicius.garcia,daniel.bernardon,mauricio.sperandio}@unipampa.edu.br
[2]AES Sul Distribuidora Gaúcha de Energia
[2]Cleverton.Vale@aes.com

***Abstract*-This work proposed an approach to centralized dispatch of service orders in electric utilities. From the knowledge a priori of all orders one day before to be assigned to a given set of the maintenance teams, computational techniques must be applied to obtain the most appropriate assignment of orders to the teams and the corresponding definition of the execution order for each team. The main contribution of this methodology refers to the productivity improvement of the teams. However, considering the significant amount of orders to be dispatched and the set of criteria to be assumed (kind of orders, location and availability of teams, deadlines, priority levels, etc), this problem do not yield a simple approach. Therefore, this work proposes a methodology involving a set of software techniques in order to manage this process and to furnish a feasible assignment, by combining a proper approach for combining the resolution of the clustering and routing combinatorial optimization problems. The proposed methodology was tested with actual scenarios of an electric utility from Brazil.**

I. INTRODUCTION

In the distribution power utilities, there is a considerable amount of orders demanded by customers or simply due to maintenance services in the distribution networks. Those services can be classified in three categories:

- Commercial: typically related to connecting or disconnecting customers from the distribution network;
- Technical: characterized by activities of inspection and/or periodic maintenance in the power distribution network;
- Emergencies: events in the power distribution network that affect the security or the quality of service in the power supply, with the corresponding attendance of emergency maintenance.

In this work, the methodology proposed considers only the centralized dispatch of commercial and technical service orders and gives the corresponding routes to attend them by the available maintenance teams.

There are strict regulations in some types of commercial orders, imposing a proper consideration since it is defined a deadline to service them, with financial sanctions in case of violation [1]. Another important aspect is the diversity of activities involved in those orders: some kind of orders can only be executed by a certain group of maintenance teams.

Managing the technical and economical attendance of demand with the available resources (human and material) corresponds to a critical task, since it involves a great amount of customer data, a considerable set of constraints related to maintenance teams and the requiring materials in the utility.

When observing only the problem of deciding which service orders should be assigned to each team, it is possible to related it with the capacitated clustering problem [5][9]. However, one important requirement is that each team must have defined its route to attend the assigned orders, this time involving the vehicle routing problem [4][6].

There is a promising scope for improvement in the procedures when considering high demand and the restrict resources in the utilities, by adopting clustering and scheduling of service orders in a centralized dispatch approach as proposed in this paper. Such proposal makes suitable the adoption of procedure patterns and can improve the productivity by reducing the travel distance of maintenance teams.

Even though there are available solutions for service order dispatch, they commonly do not consider strict policies adopted by utilities and generally are not consequence of strategic managing establish by utilities. Additionally, this is an opportunity to develop efficient and robust solutions to complex problems.

This paper proposes a methodology to define the set of orders to be assigned to each available maintenance team, with the corresponding scheduling. Sections II and III have show the formulation of the cluster and route problems and the methodology proposed, respectively. Sections IV and V present the practical results with actual data obtained from a Brazilian utility and the final remarks, respectively.

ISBN 978-3-8007-3402-3

II. PROBLEM FORMULATION

Dispatching service orders corresponds to partition the whole set into subsets in such a way that the number of subsets is equal to the number of available teams. The planning of the distribution of service orders to the teams commonly considers next 24 hours. Figure 1 presents a scenario of team georef locations in the utility supervision system that controls the execution of service orders.

Fig. 1. An example of team location scenario in the utility supervision system.

A possible definition to the dispatch problem might be one based on a graph *G=(V,E)*, where the set of vertices corresponds to the service orders and teams and the set of edges corresponds to travel distances.

- V is the set of vertices which represent the service orders; related with each vertex $i \in V$ there is a order execution time a_i (the time required to execute the procedures associated with) and a priority p_i ;
- $E=\{(i, j) : i, j \in V\}$ corresponds to the edges. A distance d_{ij} associated with each edge $(i, j) \in E$ is defined by the euclidean distance between each $(i, j) \in E$.

In order to define a problem decision, a variable x_{ijk} is then presented as follow:

$$x_{ijk} = \begin{cases} 1 & \begin{array}{c} \text{if team } k \text{ travels through edge } (i,j), \\ \forall k \in V, \forall (i,j) \in E \end{array} \\ 0 & \text{otherwise} \end{cases}$$

Since our proposal is defining the subset of orders to each team, the aim focus on reducing the total distance traveled by all teams considered, due to the correlation between the whole time to complete the service orders and the productivity of the entire process.

Therefore, the following objective function considers the minimization of the total distance, without violating the priority of service orders, classified in three groups: priority 0 assigned to commercial orders with due dates, priority 1 assigned to commercial orders without due dates and priority 2 to the remaining orders.

$$Min \sum_{k \in V} \sum_{(i,j) \in E} d_{ij} x_{ijk} + \sum_{i \in V, i \neq j} \sum_{j \in V, i < j} \sum_{k \in V} (1 - x_{ijk} - x_{jik})$$

The following constraints are considered:

- every team must not exceed its workday hours, considering the execution order time and the travel time;
- each service order must be executed by only one team;
- each team has its own default location, considering the start and the final destination of all of them.

III. THE METHODOLOGY DEVELOPED

The main conception supporting our proposal is based on the automatic centralized dispatch of service orders. Considering data related to teams and the daily demand of services, a one day schedule is developed including operation constraints as described before. These scenarios can all be registered and making possible the analysis on the impact of applying them to practice.

Solving the dispatching problem described in the previous section involves two related optimization problems: the capacitated clustering problem and the vehicle routing problem. This work proposes an hierarchical structure in a clustering first, route second approach: the high level includes the capacitated clustering problem and the low level includes the vehicle routing problem, as illustrated in Figure 2.

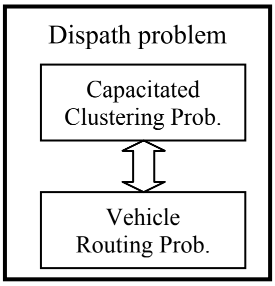

Fig. 2. Hierarchical structure for solving the dispatch problem.

This approach overcomes the complexity of the whole dispatch problem by combining solutions of these two well-known optimization problems, specially by considering particular workday hours of each team. The capacitated clustering problem has been solved by a new heuristic improved from the work of Ahmadi and Osman [1], assuming in this phase a new hierarchical model: first locating the centers and after assigning the orders to each group in such a way that the workday hours of the associated team is not exceed.

The contribution of this work refers to the algorithm developed which considers that at each order assignment, the corresponding route to attend the set of orders. This

ISBN 978-3-8007-3402-3

recalculating process must take place in order to estimate the whole time for travel through the orders assigned to each team. In case of violation, the assignment is discarded, otherwise the assignment is assumed as feasible and a new order is then considered. One can concluded that the association between the capacitated clustering problem and the vehicle routing problem occurs when the solution to the dispatch problem is evaluated. Figure 3 illustrated the developed algorithm's flowchart.

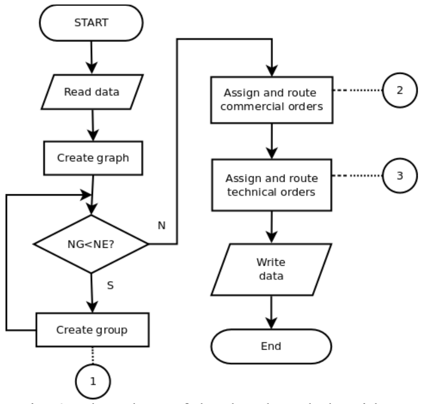

Fig. 3. Flowchart of the developed algorithm.

The algorithm starts by reading the data containing the dispatch problem considered (phase "Read data") and next the graph G is created (phase "Create graph"). The loop following these phases is charged of creating the number of groups distributed according to geographical coordinates given. In this phase, a center is defined and it is in fact an order and this point will be used as reference to assignment the remaining ones. Test "NG<NE" do not allow that the number of groups would be greater than the number of teams assumed. On phases 2 and 3, namely with circles in Figure 3, all the orders are assigned to the groups created in the phase 1: the former considers the commercial orders that have high prioritary than the technical ones, which will be assigned after in phase 3. In both cases, the workday hours is always observed.

IV. Practical Results

Case study considered in this paper has the main purpose of demonstrating how convenient and suitable can be the proposed methodology, by executing the algorithm developed to create the set of orders with the corresponding scheduling. The main objective is to compare the results obtained with this algorithm with those ones produces when manual procedures were applied assuming commonly used tasks applied by one utility.

One scenario with 290 service orders to be assigned to a given group of 5 teams, corresponding to a daily schedule. Two main aspects were critical when assigning orders to teams: the distance traveled and the time required.

In order to have a suitable comparison, the dispatch previously applied by the utility have been identified by "manual" and the solution obtained by the algorithm developed in this paper was named as "automatic". Figure 4 and TABLE I presents the results of this comparison, where one can noted the reduction in almost 60% of the total distance traveled and a reduction of almost 22% on the time required to complete the orders when visiting all the orders including in the schedule. The reduction in the distance traveled has a close relation with the time required to complete the order by assuming a default and constant speed for teams.

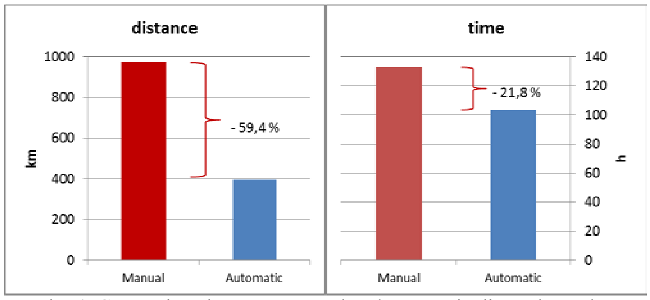

Fig. 4. Comparison between manual and automatic dispatch results.

TABLE I
COMPARISON BETWEEN MANUAL AND AUTOMATIC DISPATCH RESULTS.

	Distance (km)	**Time** (hours)
Manual	974,71	132,58
Automatic	395,44	103,62

For a better comprehensionabout the behaviour of the algorithm developed, Figures 6 and 7 illustrate the manual and automatic dispatches, respectively. One can noted that automatic dispatch has a high compactness when compared to the manual fashion, what emphasizes the contribution of this work on reducing the total distance traveled by the teams.

One significant aspect should be mentioned: the computational time required to execute the algorithm developed, in all test cases considered, does not exceed 5 seconds of commom personal computer when solving problems even with 500 up to 800 orders.

V. Final Remarks

This work has presented a new methodology to solve the centralized and automatic service order dispatch problem in electric utilities. This methodology is able to define a subset of orders to be assigned to each team considered and also gives the corresponding schedule.

Assuming an hierarchical structure when solving the dispatch problem involving the capacitated clustering and the vehicle routing problems allow us to produce effectiveness solutions in a reasonable computational time.

Practical results have been promising when observing the reduction on the travel distance and the corresponding effect on the time required. This context makes possible to have an improvement on the whole productivity of teams, by

ISBN 978-3-8007-3402-3

emphasizing this time reduction on doing additional service orders.

Future works might involve investigations about additional algorithms to evaluate the reduction on traveled distance, with particular attention to the route design.

ACKNOWLEDGMENT

The authors would like to thank the AES SUL Distribuidora Gaúcha de Energia SA for financial support provided to the project "Gestão Estratégica operacional - otimização de rotas e despachos de ordens de serviço".

REFERENCES

[1] Brazilian National Agency for Eletrical Energy, Resolution 456, 29th november 2000..
[2] Ahmadi S., and Osman I.H., 2005. Greedy random adaptive memory programming search for the capacitated clustering problem. European Journal of Operational Research 162(1):30–44.
[3] Chiou Y-C, and Lan L.W., 2001. Genetic clustering algorithms. European Journal of Operational Research 135: 413–27.
[4] Choi, E., Tcha, D-W., 2007. A column generation approach to the heterogeneous fleet vehicle routing problem. Computers & Operations Research 34: 2080-2095.
[5] França P. M, Sosa N. M, and Pureza V., 1999. An adaptive tabu search algorithm for the capacitated clustering problem. International Transactions in Operational Research 6:665–78.
[6] Haghani, A., Jung, S., 2005. A dynamic vehicle routing problem with time-dependent travel times. Computers & Operations Research 32: 2959-2986.
[7] Lorena L.A, and Senne E.L.F., 2004. A column generation approach for the capacitated p-median problems. Computers & Operations Research 31:863–76.
[8] Mehrotra, A. Johnson, E. L. and Nemhauser, G.L., 1998. An optimization based heuristic for political districting, Management Science 44(8): 1100–1114.
[9] Osman I, Christofides N., 1994. Capacitated clustering problems by hybrid simulated annealing and tabu search. International Transactions in Operations Research 1(3):317–36.
[10] Ríos-Mercado, R. L., Fernández, L., 2007. A reactive Grasp for a commercial territory design problem with multiple balancing requirements. Computers & Operations Research 3: 755-776.

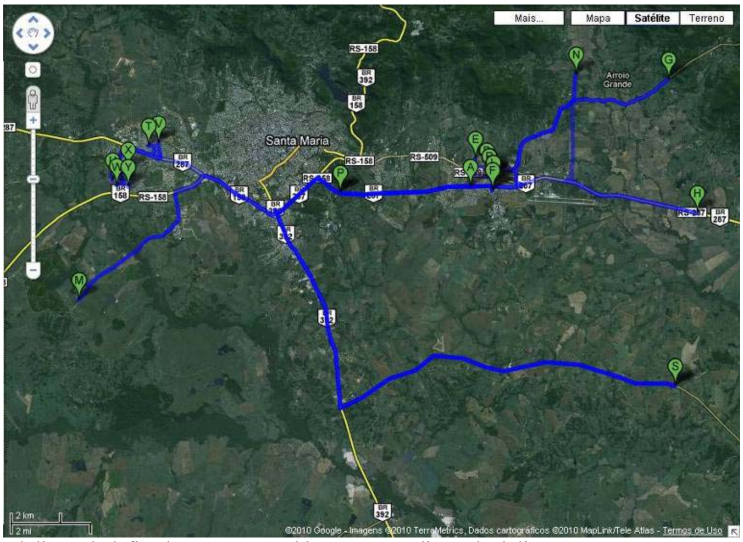

Fig. 6. Manual dispatch defined to 5 teams and its corresponding scheduling.

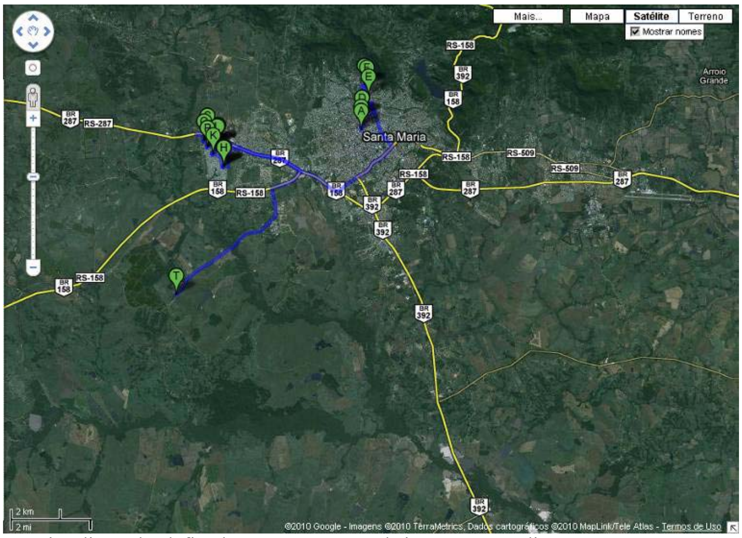

Fig. 7. Automatic dispatch defined to 5 teams and its corresponding scheduling.

ISBN 978-3-8007-3402-3